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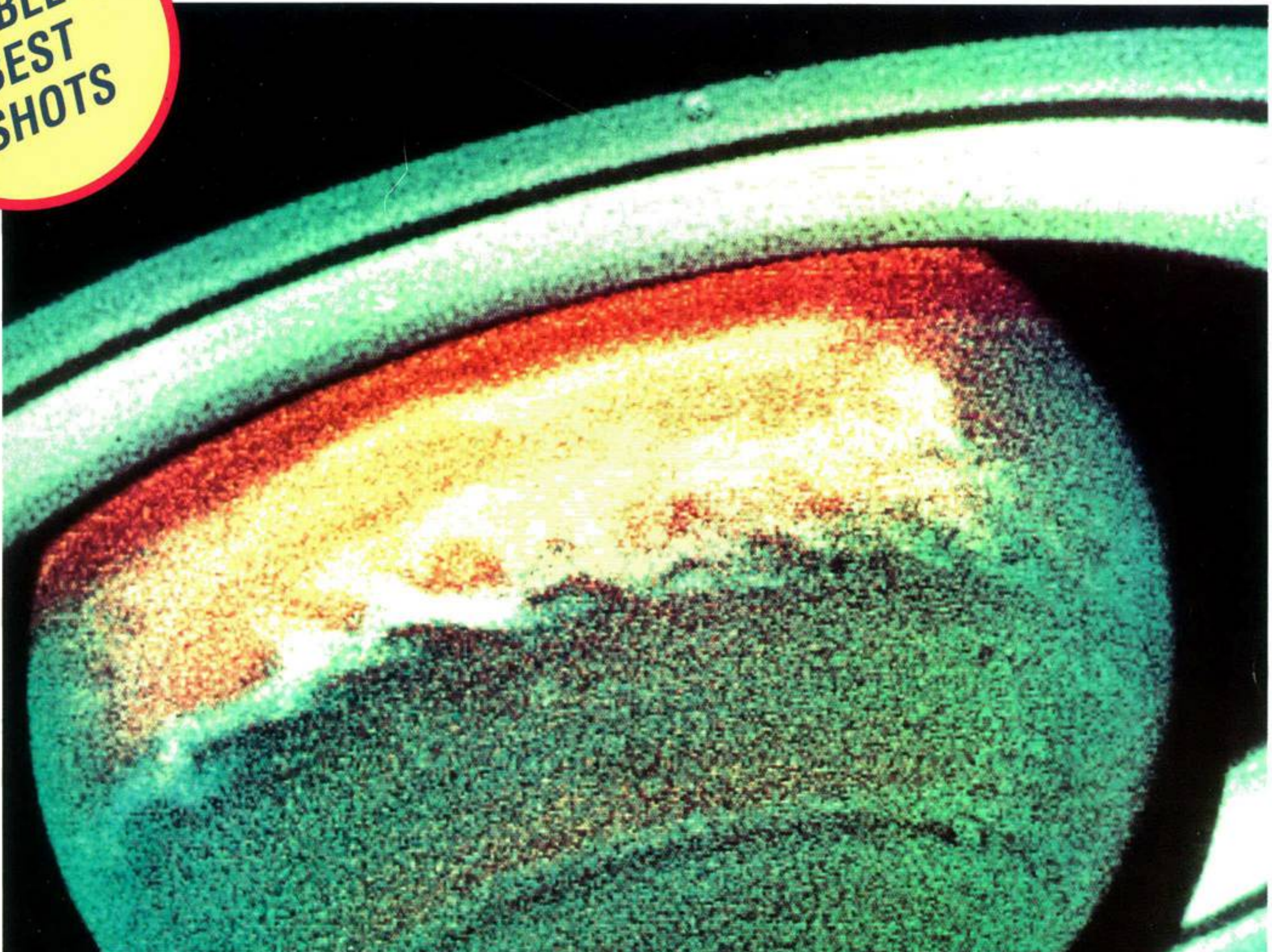
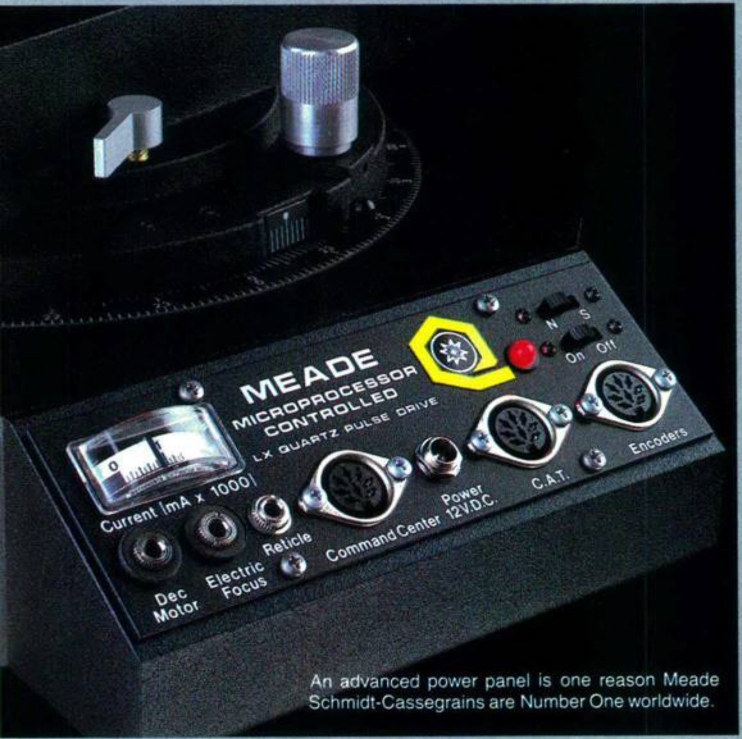


Saturn's Great White Spot

New!

Meade® Smart Drive™

Permanent Periodic Error Correction (PPEC)



An advanced power panel is one reason Meade Schmidt-Cassegrains are Number One worldwide.

Using technology developed for the Meade 16″ Schmidt-Cassegrain, the Smart Drive yields observatory drive accuracy on all Meade Premier Series 8″ and 10″ SCT's:

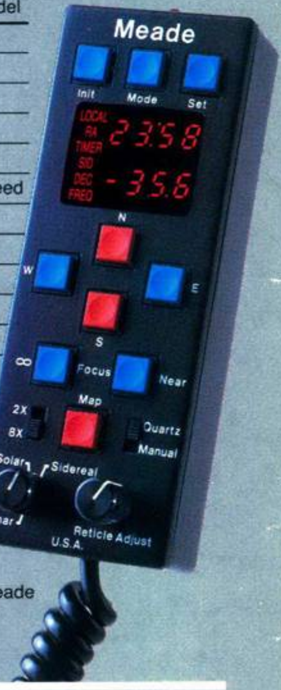
- **Automatically effects microcorrections** in the telescope's drive rate, to compensate for recurring worm gear errors.
- **Once programmed into its microprocessor memory,** required periodic error corrections are **permanently** retained by the Smart Drive—even when the telescope is turned OFF.
- **Competing "un-smart" periodic error correction devices** require that you re-train the periodic memory algorithm **each time you use the telescope**—a chore at best.
- **Meade Smart Drive technology reduces worm gear periodic error by up to 90%,** enabling vastly easier long-exposure astrophotography, with far fewer required corrections and fewer chances for guiding errors.
- **The Smart Drive is now available on all Meade 8″ and 10″ Premier Series Schmidt-Cassegrains**—from the budget-priced 8″ 30-Series to the advanced 10″ 70-Series, and on every model in between.
- **Using optional CCD's currently available,** the Smart Drive can be programmed to yield periodic errors as low as 1 arc sec.!
- **Previous Meade 8″ and 10″ Schmidt-Cassegrain models** may be upgraded to the Smart Drive—see your Meade dealer for details.
- **For complete information on the Meade Smart Drive**—and a point-by-point comparison with competing models—send $3.00 for your copy of the Meade 1990 Catalog #90C.

More Reasons Why Serious Amateurs Worldwide Buy Meade Schmidt-Cassegrains:

Month after month, year after year, in Japan, in Europe, and in the U.S.A., Meade Schmidt-Cassegrains outsell the competition. Why? Among other reasons, compare the hand control/power panel standard-equipment listings of the Meade 8″ 2080/Model 50 (our mid-price-range 8″ SC) with the competition's top-of-the-line 8″ model that sells for hundreds of dollars more! You get more for your money with a Meade.

	Meade 8″ 2080/Model 50	Competing 8″ Model
North-South Operation	Yes	Yes
Map Light	Yes	Yes
2X Corrections East-West	Yes	Yes
2X Corrections North-South	Yes	**No**[1]
Declination Motor	Yes	**No**[1]
RA Slewing	8X speed	**4X** speed
Declination Slewing	8X speed	**No**[1]
Continuously Variable Freq. Control	Yes	**No**
Illuminated Reticle Control	Yes	**No**
Optional Digital Readouts	Yes[2]	**No**
Encoder Outlet	Yes	**No**
AC and DC Adapters	Yes	**No**[3]
Ammeter	Yes	**No**
CAT™ Computer Outlet	Yes	**No**

[1] Optional Dec. motor priced at $170 additional. [2] Includes digital coordinate readouts; digital timer; RA freq. display with King rate; local time; sidereal time. [3] Optional adapters priced at $58 additional.



The full-featured hand controller of Meade 8″ and 10″ Premier Series SCT's.

Meade Optical Systems—The Best Gets Better: Long recognized as the finest commercially-produced Schmidt-Cassegrains available, Meade SC optics have now been refined still further by the addition of new state-of-the-art laser collimators. *Meade optical technicians now orient, collimate, and test Meade SC optics to tolerances that competing SC's simply can not reach on any consistent basis.* Meade 8″ and 10″ SC optics are warranted, without qualification, to be the smoothest, most precisely corrected SC systems ever manufactured.

U.S. and Canada Dealer Locations & Assistance

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"I did not feel it was possible to produce quality Schmidt-Cassegrains to the rigid optical tolerances demanded by an f/6.3 system . . . you have removed all my doubt."

Over the past 12 months Meade Instruments has removed doubts about optical quality from the minds of thousands of serious amateurs. For over that period we have undergone perhaps the most important quality assurance improvement program in the history of the industry. The result: ***never before have amateur astronomers been able to purchase optical systems of the consistently superlative quality that Meade Instruments now makes available.***

This fact has been confirmed over and over again in recent months, as the following letter attests:

August 16, 1990

"Recently I ordered five of your f/6.3 Model 2080/LX6 Schmidt-Cassegrains for classroom/lab instruction at Santa Rosa Junior College. Allow me to take a few moments of your time to praise the quality of your product.

At our College we have a special lab class in which students learn how to observe and photograph through astronomical telescopes. I ordered your f/6.3 LX6 purely for the benefit of obtaining deep sky pictures of nebular objects in 40% of the time required with an f/10 system. However, I must admit I was skeptical about the optical quality of this shorter focal ratio system.

Being an instructor of astronomy for 18 years, as well as an owner of a 6" Roland Christen refractor, I have grown to recognize and appreciate quality optics. Quite frankly, I did not feel it was possible to produce quality Schmidt-Cassegrains to the rigid optical tolerances demanded by an f/6.3 system. Well, you have removed all my doubt.

In viewing Messier objects, planetary detail, and in resolving double stars, all five of your LX6's outperformed the best of our five [competing brand of 8" Schmidt-Cassegrain] telescopes. All five of your instruments showed a smooth optical surface properly corrected as revealed by the "in-and-out-of-focus" star test.

Thank you for developing an instrument which satisfies the demand for both "fast" astrophotography and quality high-power visual work."

Sincerely yours,

Ron Smith, Chairman

Earth & Space Science Department
Santa Rosa Junior College
Santa Rosa, CA

Some weeks later we received a second letter from Mr. Smith:

September 20, 1990

"It has now been three weeks since we took delivery of our Meade 10" f/6.3 Model 2120/LX6 Schmidt-Cassegrain.

Last week, on September 11, my students viewed Saturn and assorted deep sky objects with the Meade 10," side-by-side with a [competitor's] 8" f/10 SCT. Without any exceptions every student preferred the image of Saturn through the 10" f/6.3 compared to the [competing] f/10 telescope.

On a night of good, but not excellent, seeing all of us easily observed Cassini's Division, five satellites, and the subtle cloud band encircling Saturn's disk. On high power deep sky objects, such as the "double-double" in Lyra and the Hercules globular cluster, every student again remarked that the Meade 10" f/6.3 yielded clearer, sharper images.

Thank you for manufacturing this superb optical system."

If you're looking for the finest optics currently manufactured for the advanced amateur, look no further. Look to Meade.

Meade 2080/Model 56
8" f/6.3 Schmidt-Cassegrain.
Shown with optional Digital
Readout System.

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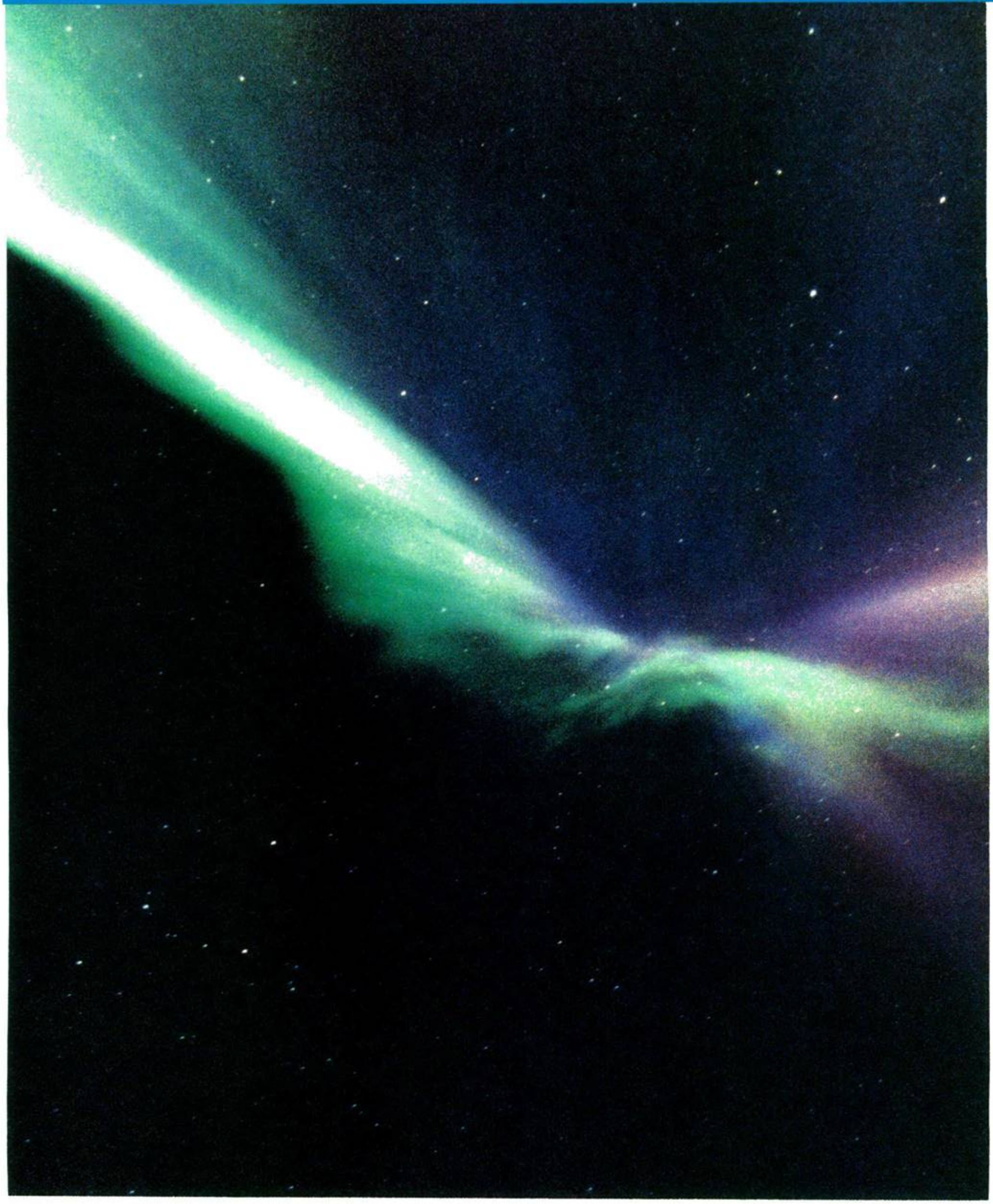
DRAPERIES OF LIGHT hung in the sky on several nights last August during colorful aurora displays. Martin Guth captured this auroral curtain in a 10-second exposure on Kodacolor VR-G 1600 film.

ON THE COVER: The Great White Spot that emerged in Saturn's equatorial region in late September 1990 has attracted enormous interest from professional and backyard astronomers alike. This false-color image taken by *Hubble* on November 9 combines a blue-light frame with an infrared one. For more on the Great White Spot and *HST*, see pages 22 and 30. Photo courtesy NASA and Space Telescope Science Institute.



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The Audit Bureau

Behind the Scenes

RAPID CHANGES IN ASTRONOMY

Timeless, eternal, enduring. These are words that we could once safely apply to the wonders of the night sky. No more. Today astronomy changes with startling rapidity. Look back with me, to the astronomy of February 1990.

One short year ago, a little-known spacecraft named *Magellan* was on its way to Venus, an enigmatic world shrouded in clouds. Earth-based radars had glimpsed the planet through the veil, and Soviet *Venera* spacecraft had made preliminary reconnaissance of Earth's "twin sister" world. Venus was a hot goddess, volcanic some said, and we knew little more.

A year ago *Hubble Space Telescope* was on the launch pad, checked and certified perfect, and the world waited with bated breath for astronomical wonders from *Hubble*. Press releases spoke glowingly of *Hubble* as the "resolution machine" that would explore the outer limits of the universe. We could barely contemplate the surprises in store for us.

In the amateur sphere, the hottest news was of films and telescopes. Only a few brave souls armed with four years of engineering coursework in digital electronics dared experiment with high-tech devices like CCD cameras.

Today it has all changed. *Magellan* is NASA's success story, mapping an entire planet with flawless precision. Only a few minor interruptions here and there have disturbed the steady flow of gigabytes from 200 million miles away. Strip by strip, we're starting to see veiled Venus more clearly than we can see the bottoms of our oceans here at home. We bring you up to date on Venus beginning on page 44.

Hubble, though it can be repaired, has been a vast embarrassment to NASA. The general public has obviously not absorbed the fact that *HST* is at least 60% functional and is actually producing breakthrough scientific results possible only from outside Earth's atmosphere. If you are like me, you've found yourself explaining to friends and neighbors over and over again that *HST* is working and will be repaired. Our lead story on *HST* begins on page 30.

And CCDs. You probably don't own one, and you may not want to. At least not yet. But you can't escape the talk and the attention they have received, and you're certainly aware that something new has come into amateur astronomy. On page 70 you'll find a portfolio of recent CCD pictures taken by amateur astronomers.

Yet the stars endure except, perhaps, for the odd nova now and then. Step outside on the next clear night. Let your eyes adjust to the darkness, and look up. The stars are still there, much as they have been for billions of years.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

Is Space Our Destiny?

I am troubled by the assertion by Daniel Bricker (Astronomy Letters, November 1990), that "man was not meant to utilize space."

The exploration of space represents the integration of every field of scientific investigation. Historically, the benefits of scientific inquiry have been the prolongation of the human life span and a vast improvement in the quality of human life. Astronomy itself has allowed us to throw back the shroud of superstition and ignorance in order to better understand the real universe in which we exist.

On a more practical level, it's easy to see the enormous contribution space exploration has made for the betterment of humanity. No other government-funded program returns $7 to the economy for every dollar spent.

Furthermore, by exploring space we learn not only about the environment of space but also about ourselves and our place in the universe. Claiming that man was not meant to utilize space is tantamount to claiming that man was not meant to utilize any inhospitable environment. Clearly we have benefited from exploration of the ocean depths and the frigid Antarctic wilderness. One could also claim that man wasn't meant to fly, but today commercial aircraft represent the best and safest way to travel long distances.

Despite conservation efforts we humans will some day exhaust our materials and energy resources. On a planet of limited resources, this fact ultimately limits survival. I suggest that mankind is meant to survive, and will at some distant point take to the stars in order to do so. — *David Lyttle, President, Miami Valley chapter of the National Space Society, Dayton, Ohio*

Reviewing the NGC-MAX

I very much enjoyed your review of the NGC-MAX (November issue). However, I question the necessity and accuracy of such a device. If the digital circles have an error of 0.5°, objects being sought could lie outside the field of view of a 1-1/4" low-power eyepiece. With my 8-inch f/10 SCT, such an eyepiece yields a 0.8° field. I've found that careful use of manual setting circles after good polar alignment usually brings a desired object within the field of view of a 2" low-power eyepiece. Such an eyepiece yields a 1.4° field of view in my scope.

Astronomers on a limited budget should consider a 2" diagonal and low-power eyepiece as an alternative to

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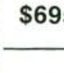

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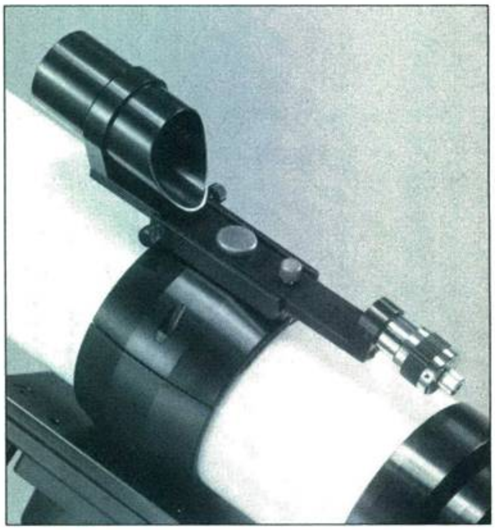

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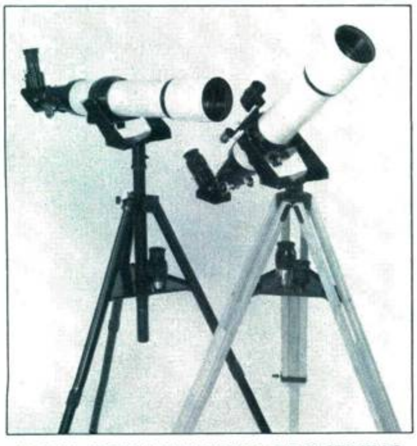
The Panoramic Mount is available with your choice of either an aluminum or wood tripod. The lightweight aluminum tripod has the same great features of the tripod used in the Tele-Pod. The wood tripod is beautifully crafted from American ash for added vibration damping. Both tripods include a convenient accessory tray.



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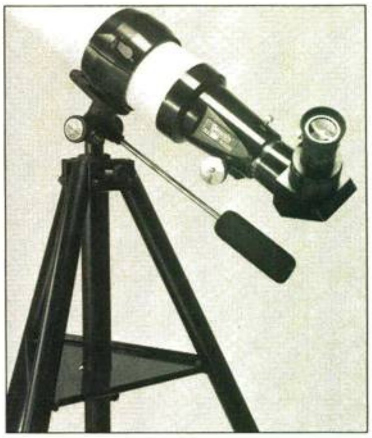
Tele-Pod is equipped with our new Uni-Lock spring-loaded head, featuring a convenient single handle control for both altitude and azimuth movement and locking. Simply screw the unique quick release adapter into the telescope base. Place your scope in the nylon tube nest for added stability. Lock the adapter and you're set for an evening's observing in seconds.

Anodized aluminum legs extend from 28" to 47" with an additional 18" of column extension. Rubber "foot-pads" contain retractable spikes for soft surfaces. Removable tray adds convenience and rigidity. The whole package weighs just 5 lbs.

Tele-Pod delivers a sturdy platform in a handy, lightweight package. Great for travelling quickly and easily with your telescope or camera.



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Systems Mount

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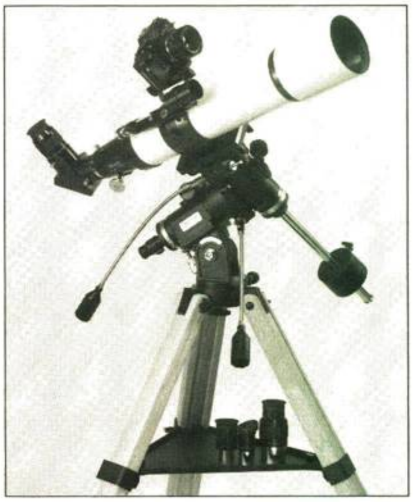

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A Tele Vue 2x BIG Barlow will have a BIG impact on your observing. As with all Tele Vue Barlows, Al Nagler designed the BIG Barlow to improve eyepiece and telescope performance. Perfect for doubling the power while retaining the eye-relief of all Tele Vue eyepieces. Ideal for eyeglass wearers who love our 40mm and 32mm Wide Fields with their rubber eyeguards, but want more power.

The Big Barlow perfectly complements the stunning performance of Tele Vue's fast refractors. The multi-coated high index doublet and anti-reflection barrel threads maximize contrast. It even improves our competitor's eyepieces and telescopes!

The 2" BIG Barlow includes a parfocal 2" to 1-1/4" adapter, threads for 48mm filters and a captive lock-screw.

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AL IS INTO BARLOWS

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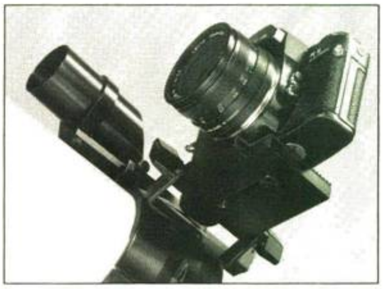

PIGGYBACK ON GENESIS

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some observers, the catalog aspect of the NGC-MAX and ability to eliminate polar alignment may be less valuable than wide-field views and an enhanced ability to see faint, extended objects. While one accessory isn't a replacement for the other, I've found that a 2" eyepiece, manual circles, and a star chart allow perfectly efficient use of my telescope. — *Andrew Jaffe, Bedford, New Hampshire*

I am a proud owner of an NGC-MAX. While some people might think that using such a device is "cheating," I feel that while you may not know what stars you're hopping past, in the end you spend more time viewing the objects you want to view. The NGC-MAX opened up a whole new world of fun for me and my telescope.

The reviewer's claim about short battery life baffled me. I received my unit six months ago and have been to three star parties, many local observing sessions, and some astrophoto get-togethers. Thus far I've had no problem whatsoever with the battery.

Overall, I'm impressed with the NGC-MAX. I know it's hard to justify the cost. You could practically buy another telescope. But it's certainly one accessory that I'll enjoy for years to come. — *Dave Young, Edwards, Colorado*

Taking the Easy Road

In "Through the Eyepiece" for November, Rick Shaffer offered a familiar way to calculate exit pupil for an eyepiece by dividing the telescope's aperture by the eyepiece magnification. However, there's an easier way to determine exit pupil for any eyepiece. Simply divide the eyepiece focal length by the telescope's focal ratio. A 32mm eyepiece used in an f/8 telescope yields an exit pupil of 4mm (32mm divided by 8).

With this method, it's not necessary to compute the power of the eyepiece in order to determine the exit pupil, and you never need to convert focal lengths or apertures from inches to millimeters.

Used on an 8-inch f/10 telescope and a 10-inch f/10 telescope, a 10mm eyepiece has the same 1mm exit pupil, but provides different magnifications. — *Barry L. Johnson, Blue Bell, Pennsylvania*

The High Cost of Telescopes

I've followed the ongoing discussion in your letters column over the high cost of telescopes with great interest. Certainly telescopes are expensive, but hasn't this always been the case? Our perception of today's high prices is caused in part by a quirk of history. From the late 1940s to the late 1960s, the United States enjoyed a rising prosperity with remarkable gains in wages and the standard of living, while inflation remained stable. In fact inflation was at its lowest during recent history in the 1950s and 1960s. Excellent war surplus optics were available for pennies on the dollar and telescopes from commercial manufacturers remained at the same price levels for 10 or 15 years. For example, the Questar 3-1/2 sold for $995 in 1956 and still sold for that price in 1967. The prices of Unitron refractors were the same in their 1956 and 1970 catalogs.

Then inflation caught up with amateur astronomy. The optics industry became labor intensive — at least that was the case for precision optics. Raw materials escalated in price and companies tried to meet higher wage demands placed upon them by workers and also government-imposed anti-pollution standards. At the same time, amateurs became aperture and gadget crazy. The result was that the basic, 6-inch f/8 reflector dropped out of sight. As advertisers pushed portability, 3-inch and 4-inch refractors dropped out of sight.

Despite this unfortunate trend, amateurs can still buy a good telescope for $500 to $1,000 — for example, a well-made 3-inch refractor or even a short-focus 6-inch reflector. The problem now is that beginning amateurs have set their sights too high, partly because manufacturers have told them that they must have a big scope to see anything.

Frankly, I'm tired of hearing the complaints about telescope costs. In 1956 I earned $100 for a first telescope by mowing lawns and walking a paper route. Later I sacrificed the "normal" teenage activities to save up enough money for a 4-inch refractor. Even a youngster can save up enough money today to buy a good first telescope through the "Reader Exchange" section of ASTRONOMY.

Those hopelessly infected with aperture fever should either fork over the money for a large scope or do what all amateurs did 50 years ago — build one themselves. Those who aren't willing to put forth some effort to get what they want are one thing and one thing only — lazy! — *Rodger W. Gordon, Nazareth, Pennsylvania*

Plaudits for NASA TV

I recently discovered that NASA has its own cable television channel on which JPL has broadcast regular updates on the *Magellan* mission to Venus. Occasionally someone on NASA Select, as it is called, conducts short interviews with scientists who show and discuss various images. When the Shuttle is orbiting, long segments of Earth images from the Shuttle are broadcast.

This is a wonderful idea. The programs are sparse — often a listing screen is all that appears. I hope NASA will increase the breadth of coverage they present on NASA Select. I would love to watch Earth from space, to see uncut film from orbiters. It would be fine to have someone talk about the images some of the time.

I think that if NASA's television service were more highly publicized, it would make people more likely to support funding for space-related projects. Are you listening, NASA? — *Elizabeth H. Bohlen, Cambridge, Massachusetts*

— It's not NASA that should be lobbied but your local cable television company. Not all cable companies carry NASA Select, and those that do don't advertise the fact much. If more people had access to this channel, NASA might be encouraged to put more effort into its productions. As it is now, most of the broadcasts are designed for NASA's internal use, not the general public.

Can't We Punish Them Some More?

I must take exception to Richard Berry's editorial in the November issue, wherein he forgives and forgets the problem plaguing the *Hubble Space Telescope.* Berry's contention that complaining about the problem is pointless is way off the mark. That such an unbelievable error could have been made and gone undetected for so long is totally unacceptable. The people responsible for this outrage should be held accountable. (I can imagine the unseemly scramble for cover that must have taken place when all of this hit the fan.) Being angry about the problem is not "whining." It is justified shock and outrage. Isn't Mr. Berry angry along with everyone else? I suspect he is despite his "noble" approach in defense of NASA. — *Ron Cardinale, South San Francisco, California* □

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

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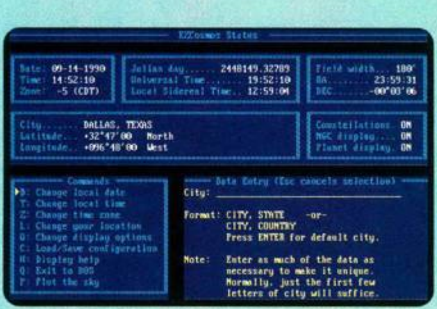

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──────────────────── EZCosmos Status ────────────────────
Date: 09-14-1990   Julian day...... 2448149.32789   Field width... 180°
Time: 14:52:10     Universal Time....... 19:52:10   RA.......... 23:59:31
Zone:  -5 (CDT)    Local Sidereal Time.. 12:59:04   DEC.......-00°03'06

City....... DALLAS, TEXAS                           Constellations. ON
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 C: Load/Save configuration
 H: Display help              Note:   Enter as much of the data as
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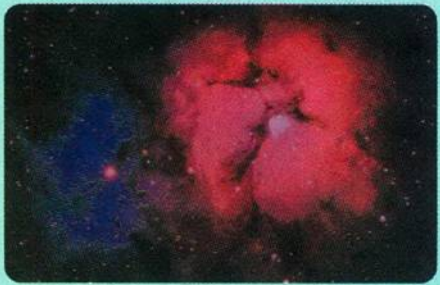

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THIS CLUB'S FOR YOU

by Karen Saunders

Once I got the Moon and its phases figured out, I thought I was well on the way to being an amateur astronomer.

I could now enter my golden years secure in the knowledge I was up to any questions about the Moon that my grandchildren might throw my way. (Well, I'm not actually ready for the golden years yet, but I like to plan ahead.) I even managed to get on speaking terms with a lot of the constellations — once I wised up to the fact they don't always look like the diagrams in the books.

At last I had arrived.

Instincts as old as the universe soon began nudging me to take on the "big guys" — shimmering nebulae! breathtaking galaxies! diamond-sprinkled star clusters! Mine, all mine, to search out and visit whenever the mood struck. I tell you, I felt more than ready to join the exalted ranks of the select few who had learned the secrets of finding these massive, but sometimes obscure, objects.

(OK, I admit a five-year-old could probably find the Pleiades, too, but at least I knew which month to start looking. And no matter what my fellow amateur astronomers say, it wasn't *totally* an accident the night the Double Cluster slipped into my field of view — I knew it was around there somewhere.)

Nebulae? Galaxies? I figured they would be no big deal to zoom in on. A little practice and in no time at all I'd be impressing family and friends with my wondrous ability to bring the universe to their backyards. My great chance for glory came when a neighbor meandered over and asked to see a nebula.

"Sure, no problem," said I, confidently.

Well — three star maps and one hour later, I sheepishly admitted I was having just a teensy bit of trouble finding anything that even resembled a nebula. (Where is M42 when you need it?)

By this time, four more neighbors had joined us. I guess it was a funny sight: five people who had never before seen one trying to figure out a star map, and me, one less-than-confident amateur astronomer, praying they would stop with all the questions and just go away. I shudder in remembering it.

Well, it was definitely time to consult the experts. I recalled reading about astronomy clubs, so I began touring the local groups in hopes they could help me before I embarrassed myself right out of astronomy.

One of the first things I learned was a basic definition that encompasses all clubs. Simply put, an astronomy club is a group of people with a common interest in astronomy who get together to exchange ideas and information, add to their knowledge, observe the night (and daytime) sky, and introduce new people to the fun of star gazing.

Three star maps and one hour later, I admitted to having just a teensy bit of trouble finding the nebula.

Once I had tucked that information safely away in my mental file cabinet, I looked into different types of clubs. A little nonchalant nosing around led me to realize that not all clubs are created equal.

By this I mean that different clubs have different priorities and interests. What a particular club chooses to focus on depends on several things — for example, the reason it was originally formed. The founding purpose could be anything from general astronomy to exploring the thrills and horrors of making your own telescope. Or the club may follow the interests of its current leading members. For instance, an enthusiastic group of photographers in the membership can lead the club into experimenting with old and new methods in astrophotography.

I found some clubs are oriented to gathering data and making serious observations to assist professional astronomers. These activities included monitoring meteor showers, studying the cycles of variable stars, keeping track of sunspot activity, and observing and recording occultations of stars by the Moon. (If any of these activities interest you, in addition to local clubs, there are several national organizations you can contact for information about programs for beginners.)

I plan to get involved with one of the clubs that specializes in meteors — as soon as I learn to stop swiveling my neck trying to catch them all.

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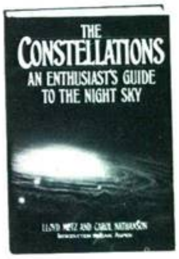
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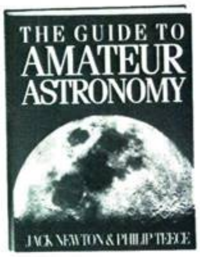
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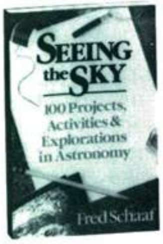
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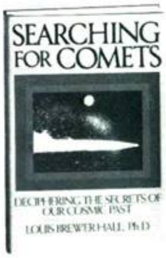
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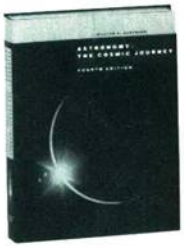
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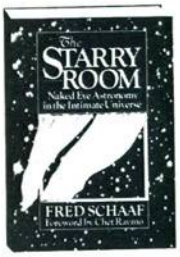
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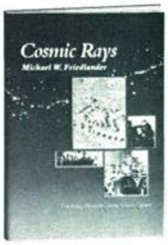
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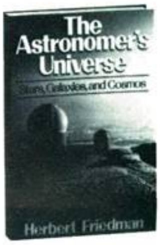
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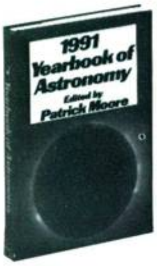
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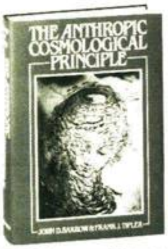
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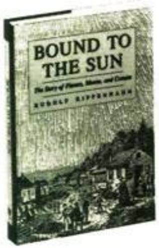
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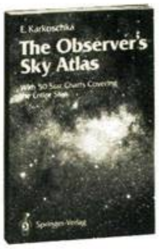
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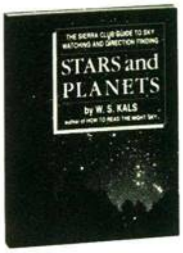
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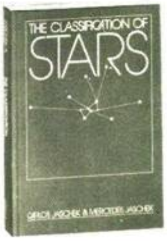
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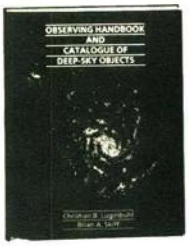
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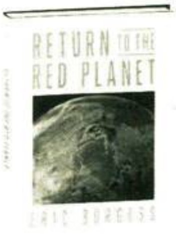
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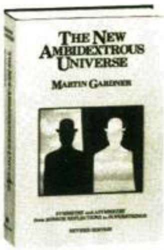
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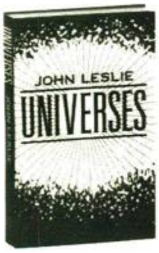
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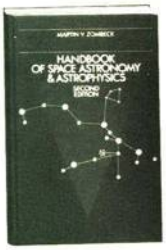
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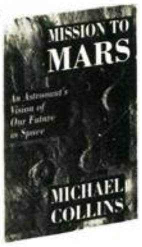
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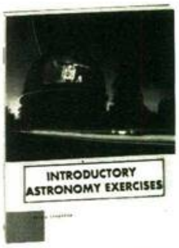
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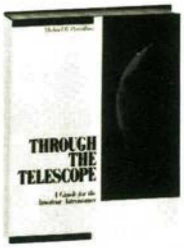
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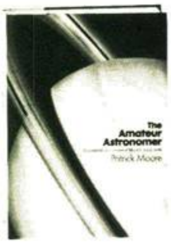
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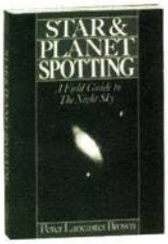
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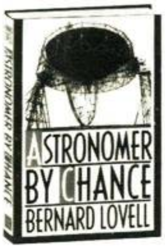
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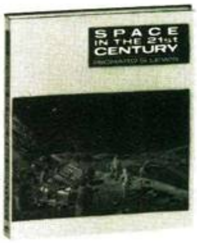
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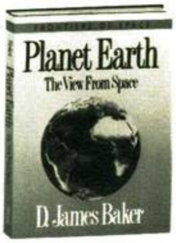
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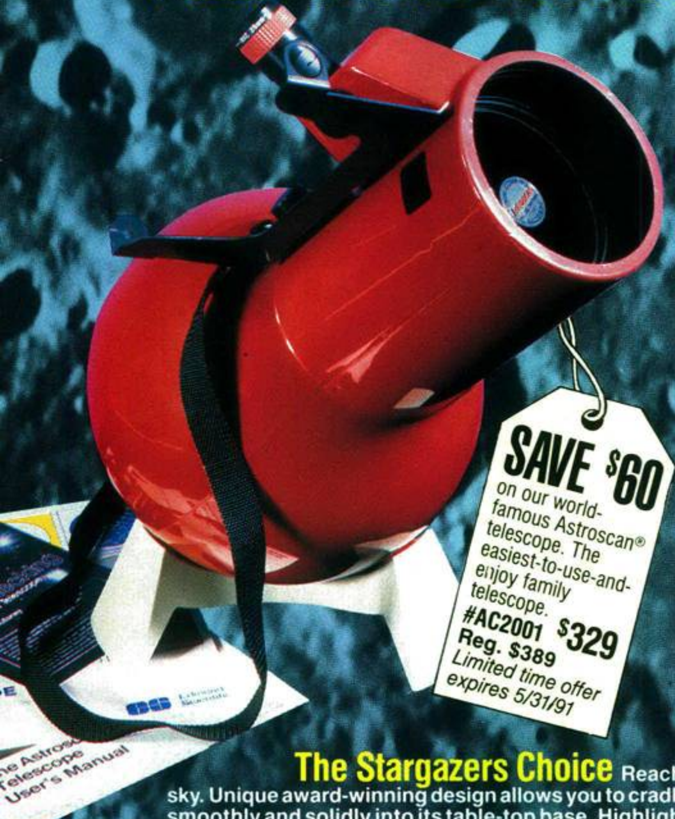
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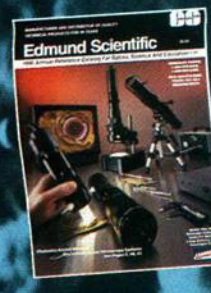

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to show an interest in astronomy, check with the local clubs to see if they're set up to handle youngsters. You'll also find junior clubs and programs for kids at local planetariums, science centers and museums, community colleges, county recreation centers, and Scouting groups.

Many of these offer hands-on actities for youngsters which are geared to their interest level. The staff of each is trained to guide and develop the fascination kids often have about astronomy.

Since my knowledge of astronomy fell into the "Help, I don't know what I'm doing!" category, the general-interest clubs appealed most to me. The benefits they offered were just what I was looking for.

Star parties. These are both educational and downright awe-inspiring. I feel star parties are the best way for beginners to learn about the night sky (see Viewpoints, October 1990).

Why are they so good? I found that having an experienced observer beside me leading the way enabled me to relax and quit worrying about the things I wasn't ready — or equipped — to tackle yet. The club members, bless 'em, managed to get me steered in the right direction without losing their sanity. I even learned how to starhop my way to a particular object, a technique which has since kept me from giving up in frustration.

Club observatories & scopes. Here's an inside scoop: You don't have to own a telescope to join a club. Believe it or not, I have met members who for a variety of reasons have never had their own telescope.

A club usually has scopes you can use and if you find a club that has an observatory, you're really in business. Of course, most amateur astronomers think this isn't really a substitute for having your own instrument, but if you really don't have the means to buy your own scope, the night sky is still there for you to view through other scopes.

Telescope-buying advice. If you're in the market for a telescope, members can offer advice on what's available. When I became bored with my little refractor, I decided, after looking through a variety of scopes at star parties, that I wanted a big reflector — which I eventually bought. (I'll go back to refractors as soon as I've saved enough for a 7-incher.)

Equipment discounts. Camera shops, telescope stores, magazines, and bookstores often give discounts to club members. These alone make the price of membership a great value since I

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In addition, telescope makers should note "it would be rather easy to attach the Astro Master to just about any homemade mounting I've ever seen, whether altazimuth or equatorial"– Sky & Telescope Magazine review.

Perhaps a Sky & Telescope reviewer summarized the popularity of the Advanced Astro Master when he wrote "I look at CAT's as electronic catalogues to be used right at the telescope. They have given me a chance to check out objects that I'm sure I would have ignored while I was sitting at a desk planning my night's observing with conventional charts and catalogues because they seemed too small, too faint, or too far away from an easy guide star."

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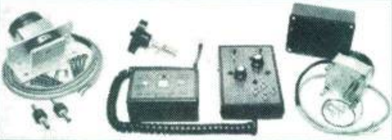

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usually find myself buying a lot of "indispensable" astronomy items.

Swap meets. These are fun! The odds are you'll find some part you've been looking high and low for at a club swap meet and at an affordable price. You can also sell or trade the gizmos you no longer need. In addition, many newcomers appreciate getting on-the-spot instruction in something's use. If members choose to donate items for sale, the profits can be plowed back in club activities.

Campouts to dark-sky sites. (Don't panic, sometimes motels are nearby.) City lights really mess up the sky, so if you've never been more than a few miles away from them, these campouts should not be missed.

The only problem I had with dark skies was not recognizing the constellations without lights flooding them. I needed detailed instructions to even find Polaris.

Club-sponsored courses and seminars. Sooner or later, the bug to learn more is going to hit you. It's the perfect time to sign up for a few courses that may be sponsored by your club at your local high school or community college. The courses typically cover a wide variety of subjects from basic astronomy to new techniques in astrophotography.

Newsletters. These little gems of literary excellence make great reading. They offer up-to-date information about current happenings in the club. If, like mine, your local newspaper gives only tiny glimpses of what's going on astronomically, the club newsletter usually fills in the gaps on late-breaking news such as newly discovered comets, *HST* updates, and eclipses.

I've found several newsletters that are as chatty as a down-home newspaper. They cover who's doing what, why, when, and where. They keep you up on things if you miss a few meetings.

Socializing. Holidays, summer picnics, and winter activities all provide time for members and their families to spend a few hours together doing plain old socializing. It's an opportunity to get to know one another on a more personal level. (After all, the world doesn't revolve around just astronomy — well, actually, I guess it does, technically.)

In my research among the clubs, I found they all had several common aspects. Among these are the meetings.

Now, the first thing you have to do at a club meeting is attend it with an open mind. If the members happen to be discussing the Fraunhofer H and K lines in the solar spectrum during the first meeting you wander into, don't assume that they are doing it just make you feel dumb.

Check the sign on the door to be sure you got the right room, and then quietly find a seat way, way in the back. In all probability, someone in the club had a specific question on the subject. Don't let this scare you away; for all you know, a year or so from now, *you'll* be looking for information like this.

Almost all club meetings are aimed to meet the interests of the majority of the members. You just have to remember that it's not always possible to satisfy everyone, every time. So if your eyes glaze over from time to time, keep in mind that your absorbing interest in stellar parallaxes probably doesn't lead the list for spellbinding topics, either. (It's also worth keeping in mind that a club with a wide variety of interests among the members has less chance of becoming static.)

Small clubs offer more of a family feeling, but large clubs usually have a greater range of interests and activities.

One of my favorite meeting activities is the guest speaker. A speaker really adds new dimensions to my knowledge since I get the information from the horse's mouth, so to speak. The question and answer period is usually very interesting. It gives you the chance to probe the mind of an expert — and saves hours of frustrating library research when the books never seem to answer the one question that's burning a hole in your mind. (Even if the guest speaker comes to you over the phone lines via a conference call, it never fails to open the door to new learning opportunities.)

I have noticed that most meetings are run informally. Of course, they are structured to follow certain guidelines and time frames, but a friendly, relaxed atmosphere sets them apart from the dreaded "corporate" meetings. Oftentimes, some of the most helpful information comes from members who have a point to make or a question to ask. As a new member, I wasn't ready to get up there and bare my soul for a while. But I learned quite a bit from the other members who showed slides and photographs of objects they hunted down.

The clubs I looked into all provided more than enough opportunity for each member to present his or her opinions, suggestions, and reports.

If your area has more than one club, you'll probably have to decide whether to join a large club or a small one. I've found small clubs offer closer interaction among the members and have more of a family feeling. Their meetings and general activities are very informal but still provide a place to learn and have fun. About the only disadvantage — but to the members, it's not always seen as a disadvantage — is that small clubs may not be able to attract top-name speakers, who as a general rule prefer to devote their time to large groups. (There are exceptions, of course.)

In a large club some people feel lost in the crowd, but I have found that it takes very little effort to find one that works closely with all members. To avoid having members jump up and down at meetings yelling, "Don't forget about me!" large clubs have many ways to keep everyone feeling like a part of one organization. These include, for example, newsletters, phone calls to notify members of changes, and periodic "What have you been doing lately?" get-togethers. The last can include barbecues, holiday parties, contests, and so on.

There's one last club benefit worth mentioning — public programs. Now even though the word "public" is floating around there, you should know that means you. Clubs sponsor a variety of activities such as Astronomy Day, school talks and demonstrations, star parties, and so on. (In fact, maybe that's how you found out about the club in the first place?) Each of these activities is a learning experience for members, also. I'm constantly amazed at how much I absorb at these functions; just when I thought I had learned it all, along comes another tidbit to store away.

In the end I joined a small informal group. We have fun, and I think that has to be one of the most important reasons for joining a club. The main other point to consider in choosing a club is the variety of interests the members have.

In our club, I notice that interwoven through all the good times and laughs is the inescapable fact that I'm learning and growing in amateur astronomy. Who knows, maybe some day I might surprise myself and discover a comet — now that I know how to do it.

Yeah, that's it, Comet Saunders! I can see it now — fame, fortune, free admission to bigwig astronomy conventions. □

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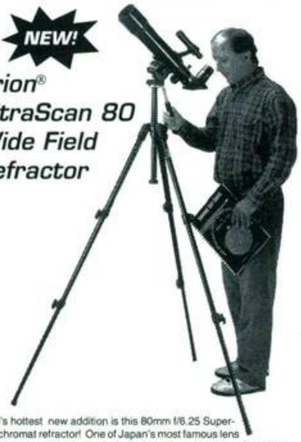

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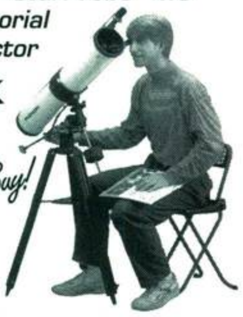

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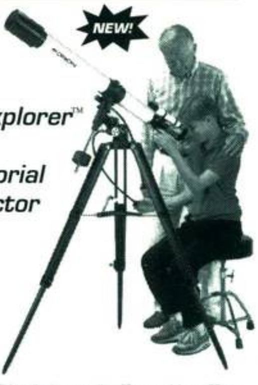

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Designed for the field tripod with padded insert to separate wedge from tripod during transportation. Specifically made for wedge combinations of Schmidt-Cassegrain telescopes up to 10" aperture. Allows storage without changing polar alignment. This blue bag is made of tear, rip and mildew resistant 100% Cordura nylon.

#15096 **$79.95** (4.65)

Orion® VariPower™ 2-3x Multi-Coated Barlow Lens

Our best barlow offers significant improvement over other models we've seen. The magnification is adjusted by sliding the internal lens cell along a calibrated scale (you don't have to poke a finger or pencil inside to do this). Fully Multi-Coated optics provide excellent sharpness, contrast and brightness. 1.25" diameter.

#8748 **$69.95** (2.59)

Orion® 3-element Fully Multi-Coated Barlow Lens

Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.

#8750 **$59.95** (2.59)

Orion® Deluxe Fully-Baffled Multi-Coated Barlow Lens

Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.

#8746 **$49.95** (2.39)

Orion® Sky Explorer™ Mini Deep Sky 8x56 Binoculars

56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view.

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Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Compare with other brands selling for much more!

Wide Field 5-element

35mm #8560 **$89.95** (2.59)

30mm #8562 **$79.95** (2.59)

25mm #8564 **$64.95** (2.59)

Medium-High Power 5-element
20mm #8566, 15mm #8568, 10mm #8570, 7.5mm #8572

$59.95 ea. (2.59)

High-Power 7-element 5mm #8574, 3.8mm #8576

$79.95 ea. (2.59)

Orion® MegaVista™ 1.25" Wide Angle Eyepieces

Incredible Fully Multi-Coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye-relief.

10.5mm- An incredible 67° field for outstanding planetary or deep space performance.

#8552 **$109** (2.79)

16.8mm- Outstanding high-contrast eyepiece with stunning 70° field ideal for deep space.

#8554 **$119** (2.79)

Orion® UltraZoom™ 7-21mm 1.25" Eyepiece

The finest zoom you can buy for your 1.25" telescope. An excellent choice for astronomy or terrestrial observing. 65°-35° field.

#8556 **$129** (2.79)

Orion® Explorer Series 1.25" Eyepieces

Remarkably affordable, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

Kellner Eyepieces-
6mm #8536, 9mm #8538, 12mm #8540, 18mm #8508, 25mm #8510, 40mm #8512

$33.95 ea. (2.19)

Orthoscopic Eyepieces- 5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526

$46.95 ea. (2.19)

Orion® Explorer Series .965" Eyepieces

Get the most from your small telescope with these fine Multi-Coated eyepieces. Standard .965" barrels fit all Japanese standard small telescopes.

.965" Orthoscopic Eyepieces-
5mm #8580, 7mm #8581
9mm #8582, 12.5mm #8583

$37.95 ea. (2.19)

.965" Kellner Eyepieces
18mm #8584, 25mm #8585
.965" Achromatic Huygenian Eyepieces- 40mm #8586

$24.95 ea. (2.11)

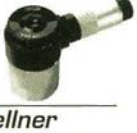
World's Finest Illuminated Reticle Eyepiece

6mm Orthoscopic design for required high-power guiding, plus unique X-Y adjustable reticle positioning for easy guide-star alignment. Wireless LED illuminator has adjustable brightness.

#8487 **$139** (2.79)

Orion® 9mm Orthoscopic Illuminated Reticle Eyepiece

9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.



#8488 **$119** (2.79)

Orion® 12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into LX/3, LX/5 and Premier drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.

#8482 **$69.95** (2.59)

77° Field UltraScan Wide-Angle Eyepieces NEW!

Unlimited visibility is yours with up to 77 degrees of field to catch your eye. High quality optical materials and superb coatings, for the ultimate in contrast and resolution.

1.25" UltraScan Eyepieces
Five optical elements utilizing the latest high refractive-index optical glass materials achieve extremely wide fields with fewer elements than many competitive eyepieces, reducing weight and cost. Each lens surface is fully Multi-Coated, for the ultimate in contrast and elimination of stray reflections. Integral rubber eyeguards.

9mm-#8420 **$99** (2.79), ***12mm***-#8421 **$109** (2.79)

15mm-#8422 **$129** (2.79), ***19mm***-#8423 **$139** (2.79)

2" UltraScan Eyepieces
These incredible oculars provide breathtaking panoramic, bright views that will astonish you!

30mm 2" UltraScan Eyepiece - This 5-element, 77 degree field UltraScan eyepiece combines the widest possible apparent and true fields with a larger image scale than our 40mm.

#8424 **$199** (2.79)

40mm 2" UltraScan Eyepiece - Orion's brightest, widest true-field UltraScan eyepiece utilizes a sophisticated 7-element design, providing a 68 degree apparent field; the widest we could fit into the 2" diameter barrel.

#8425 **$179** (2.79)

Orion® SkyGlow™ Enhanced Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters- Photographic and Visual
For use in slight to moderately light polluted areas.
1.25" Broadband Filter-fits 1.25" eyepieces.

#5660 **$59.95** (2.59)

Schmidt-Cassegrain Broadband Filter- fits rear cell of Meade & Celestron SC scopes.

#5658 **$79.95** (2.59)

52mm Broadband Filter- fits all camera T-rings.

#5668 **$66.50** (2.59)

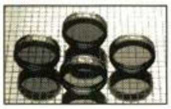
SkyGlow UltraBlock Filters- Visual Only
For severely light polluted areas.
1.25" UltraBlock Filter- fits 1.25" eyepieces.

#5654 **$79.50** (2.59)

Schmidt-Cassegrain UltraBlock Filter- fits rear cell of Meade & Celestron SC scopes.

#5656 **$99.00** (2.59)

Orion® Color Filters for Eyepieces



Solar system observations are dramatically improved by Orion colored filters. For visual use, thread one into the barrel of any standard eyepiece. For planetary and lunar photography, Schmidt-Cassegrain owners can attach the filter to the eyepiece inside the tele-extender. Can also be threaded directly into a universal camera adapter.

Basic Set of 4 Filters .965"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5510 **$29.95** (2.19)

Basic Set of 4 Filters 1.25"- Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5514 **$39.95** (2.19)

Expansion Set of 4 Filters 1.25"- Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.

#5516 **$39.95** (2.19)

Deluxe Set of 8 Filters 1.25"- Includes all the filters in our basic and expansion filter sets.

#5517 **$74.95** (2.79)

Individual 1.25" Filters- #80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544)

$11.95 ea. (.99)

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664 **$14.95** (2.11)

1.25" #5662 **$14.95** (2.11)

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Make observing more comfortable and enjoyable with one of these great chairs.

Standard Model-
Has adjustable-height center column and padded vinyl seat. Folds for easy storage.

#5935 **$39.95** (3.96)

Deluxe Model-
Is much heavier-duty, built for professional musicians. Extra thick padding, wide footprint. Adjustable and disassembles for storage.

#5934 **$89.95** (5.65)

Breakthrough Low-Price Plössl Eyepieces! NEW!

These new Multi-Coated Plössl eyepieces are incredibly low priced! Good quality optics for sharp, clear images. Precision four-element Plössl lens elements mounted in sturdy aluminum barrels. Available in 12mm, 18mm, or 25mm focal lengths, with 1.25" barrels. Buy all three for less than some single eyepieces!

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18mm-#8597
25mm-#8598

$39.95 ea. (2.39)

Orion FlexiShield™ Dew Caps NEW!

Eliminate dew problems with FlexiShield! Better performance, more rugged, and easier storage than rigid dew caps. Made of durable, unbreakable, fire-retardant Kydex™. Form into a tube with the velcro closure, or change into a flat rectangle or small-diameter tube for easy storage and transportation. No paint to chip or scratch off. They fit your telescope tube snugly, thanks to the wide rubber padding and full-length velcro closure. Nothing needs to be attached to your telescope; needs no screws, no tape, no glue. Once in place, they are very rigid and do not block the optical path. Models to fit most telescopes.

90mm Celestron/Meade Spotting Scopes #4203 **$24.95** (2.39)

90mm Celestron Rubber Armored Spotting Scopes #4205 **$24.95** (2.39)

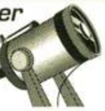
4" Meade Schmidt-Cassegrain #4204 **$24.95** (2.39)

8" Celestron/Meade Schmidt Cassegrains #4200 **$39.95** (2.39)

10" Meade Schmidt Cassegrains #4201 **$49.95** (2.39)

11" Celestron Schmidt Cassegrains #4202 **$59.95** (2.39)

Orion® Dew Zapper



Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

8" Dew Zappers-fit all Meade & Celestron 8" Schmidt-Cassegrains

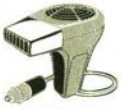
DC Model #3503, AC Model #3504 **$39.95** (2.39)

10" Dew Zappers- fit all Meade 10" Schmidt-Cassegrains

DC Model #3506, AC Model #3508 **$39.95** (2.39)

Dew Remover Gun

Moisture that interferes with viewing dissipates quickly with this 12V DC, 156 watt warm air gun. Has 4-1/2' cord.



#5601 **$17.95** (2.48)

Starlite Red LED Flashlight

The Starlite is the only adjustable-brightness night-vision red flashlight. Lifetime solid-state LED can't burn out. Extra efficient electronic circuit for long battery life. Uses one 9-volt battery (not included).

#5714 **$24.95** (2.11)

Astronomer's Flashlight

Indispensable and indestructible. Has special night-vision red filter and a diffusion lens for even illumination. An essential addition to your astronomy accessories. Requires 2 D-cell batteries (not included).

#5701 **$9.95** (1.89)

Rechargeable Battery Porta-Pack

12 Amp Hour Porta Pac
Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper Battery is encased in high-impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs.

#2354 **$99 ea.** (6.23)

Orion® Dual Balance System

Unlike ordinary counter-weights, our system allows instant adjustment in both directions. Easily balances your scope to offset both piggyback loads or rear-cell cameras, 2" diagonals, and other accessories. Rigid, precision machined dovetail bar mounts to telescope in existing accessory holes.

For Meade SC 8" #5150 **$74.95** (4.65)

For Celestron 8" C-8 #5149 **$79.95** (4.65)

For Meade SC 10" #5152 **$84.95** (4.65)

Orion® T-Adapter

For prime focus photography. Use with T-ring to match your 35mm camera. For Meade, Celestron 8", 10" SC.

#5116 **$27.95** (1.89)

Orion® UltraGuider NEW!

Our newest off-axis guider for Celestron and Meade Schmidt-Cassegrain scopes. Easily adjustable prism allows wider choice of guide stars. Heavy no-flex construction. Precision helical focuser for your guiding eyepiece. Adjustable camera focal plane position. Suitable for advanced deep-space astrophotography. Compare our price!

#5139 **$119** (2.79)

Standard Off-Axis Guider
Name brand quality at a low Orion price! Our popular, precision anodized guider with fully coated prism.

#5144 **$59.95** (2.59)

Rack & Pinion Focusers

NEW!

Perfect for telescope makers or upgrading existing telescopes. These top quality focusers are designed specifically for Newtonian reflectors. Chrome plated brass & black enamel finish. Two sizes to fit your needs. Fit any size tubes.

1.25" Focuser
Quality diagonal-cut rack for smooth focusing. Secure slide-fit eyepiece holder. Integral socket for single-stalk diagonal support if desired. Knurled focus knobs.

#13017 **$44.95** (2.39)

2" & 1.25" Focuser
Large clear diameter ideal for larger scopes and wide-field optics. Massive oversized knurled knobs for easy fine focusing. Precision diagonal cut rack. Long travel for both visual and photographic use. Interchangeable 2" and 1.25" holders with set screws.

#13019 **$69.95** (3.31)

Orion® 45-Degree Erect Image Diagonals NEW!

See the world as it really is with Orion's new 45-degree erect image diagonal. Upside-down, backwards and topsy-turvy images can often confuse even the stoutest and most experienced observer. Turn it right-side-up with your choice of three models to select from.

.965 Diagonal #8759 **$59.50** (2.59)

1-1/4" Diagonal #8753 **$59.50** (2.59)

Size-Adapting Hybrid Diagonal #8755 **$59.50** (2.59)

Star Diagonals

1.25" Star Diagonal
Primarily for astronomical use, lets you view at a right angle. Multi-coated, for 1.25" eyepieces.

#8763 **$39.95** (2.39)

.965" Star Diagonal
Same as 1.25" Star Diagonal, but with standard coated optics. Works with .965" eyepieces and eyepiece holders.

#8761 **$24.95** (1.89)

2" Star Diagonal

Get the widest possible field of view from your Schmidt-Cassegrain Telescope. This star diagonal features a special aluminized and overcoated precision first-surface flat mirror.

#8767 **$89.95** (2.89)

Orion® Tele-Extenders

For high powered photography with your Meade, Celestron 8", 10" Schmidt-Cassegrain

Standard Tele-Extender
Use this Tele-Extender in conjunction with an eyepiece. Attaches to visual back of Meade or Celestron Schmidt-Cassegrain telescopes, and to 35mm camera with T-ring, sold separately.

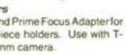
#5125 **$27.95** (1.89)

Variable Tele-Extender
Uses an adjustable extension tube, allowing magnification to be changed without switching eyepieces. Thumbscrews lock extension tube securely in place. Attaches to 35mm camera with T-ring, sold separately.

#5127 **$39.95** (1.89)

Universal Camera Adapters

Standard Universal Camera Adapters
Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately) to match your 35mm camera.



.965" #5268 **$29.95** (1.89)

1.25" #5264 **$34.95** (2.39)

Variable Power Camera Adapter

Unique sliding barrel design allows variable projection distances during eyepiece projection photography, eliminating the need to change eyepieces when magnification changes are required.

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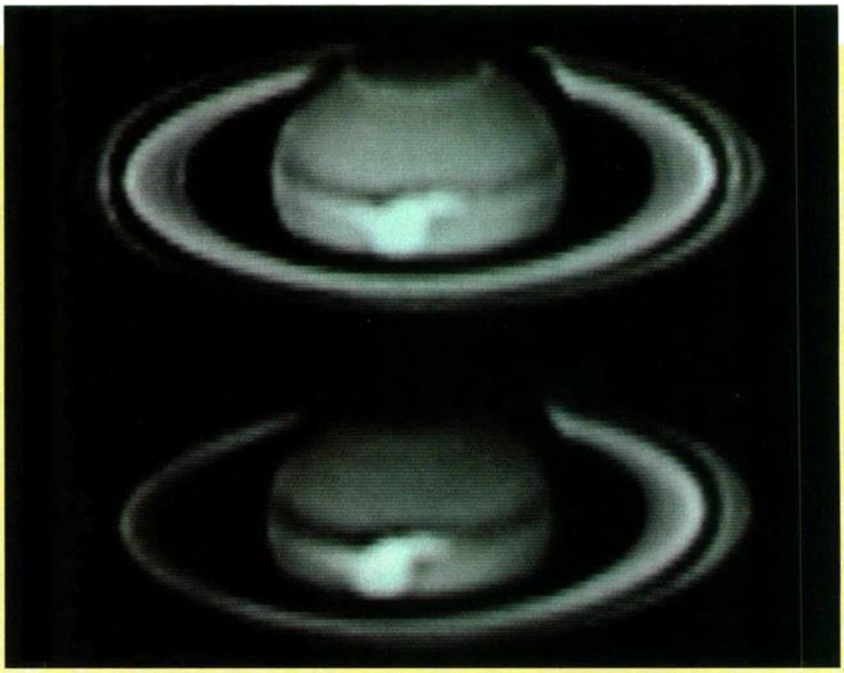
A BLACK HOLE FOUND AT LAST?

The most widely publicized black hole candidates to date have been Cygnus X-1 and LMC X-3, two x-ray emitting binary stars. But doubts have lingered about their identity. A third x-ray binary star, known by its x-ray catalog number as A0620-00, has now taken the lead as the best black hole candidate.

Writing in the *Astrophysical Journal Letters* for August 20, 1990, astronomers Carole Haswell of the University of Texas and Allen Shafter of San Diego State University pointed out that unlike Cygnus X-1 and LMC X-3, A0620-00 appears to be encircled by a readily observable disk of material. This disk provided the key to identifying the black hole. By measuring the shift in the spectral lines of the light from the disk, Haswell and Shafter determined that the object at the center of the disk must be at least 3.8 solar masses. This would place it above the critical limit of 3 solar masses for a black hole.

Earlier observations had shown that the A0620-00 system also contains a type K star known as V616 Monocerotis. The star and the black hole (accompanied by its accretion disk) waltz about a common center of gravity. As they do so, the K star and the black hole alternately move toward and away from us, a type of motion that normally shows up as a slight shift in the spectral lines from an object. In the 1980s astronomers measured this shift in the spectrum of the K star and had calculated that the unseen companion must be about 3 solar masses, putting it on the black hole suspect list. But a more precise measure of the dark companion's mass would require measuring its motion as well. Since black holes themselves emit no light, astronomers can't measure the spectrum of a black hole. Instead, Haswell and Shafter measured the spectrum of the accretion disk surrounding the hole, a disk that shares the hole's back and forth orbital motion.

These measurements, made with the University of Texas McDonald Observatory's 2.7-meter reflector, revealed that for the observed velocities to be correct the ratio between the companion's mass and the mass of the type K star must be 10.6 to 1. Since other observations showed that the type K star has at least 0.36 solar masses, the dark companion must be at least 3.8 solar masses and may well be higher. New research currently underway should narrow the mass figure down even more. But even with what we know now A0620-00 has given astronomers the best evidence yet that black holes do exist.

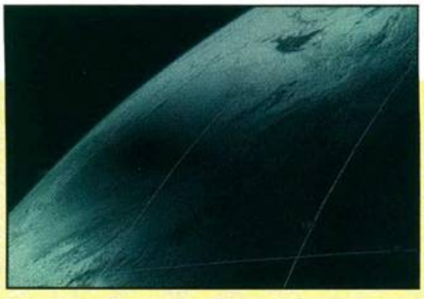


THE GREAT WHITE SPOT on Saturn, which erupted in late September, was captured in high-resolution images taken with the 1-meter reflector at the Pic-du-Midi Observatory, France. J. Lecacheux, P. Laques, and F. Colas used a 128x128 pixel CCD camera and a focal length that yielded a resolution of 0.3 arcseconds per pixel. The images were taken October 2, early in the Spot's appearance. In the weeks following, the Spot spread in longitude to form a bright belt around the entire equator, with a remnant nucleus marking the location of the original Spot. The images show Saturn in red (top) and green wavelengths. Images courtesy P. Drossart, Meudon Observatory, Paris.

DUST DEVILS ON TRITON?

Are the geyser-like plumes on Neptune's moon Triton similar to terrestrial dust devils? Two planetary scientists at Caltech, Kimberly Tryka and Andrew Ingersoll, are proposing (*Science*, October 19, 1990) that the 8-kilometer-high plumes are actually columns of dark organic material ("dust") spiraling in an updraft. The energy source driving the updraft is solar heating of unfrosted, dark patches on Triton's surface.

Tryka and Ingersoll remark that the low surface temperature on Triton (38 kelvins) permits strong convection currents to develop above any patch of



THE MOON'S SHADOW was captured by a *GOES* weather satellite as the shadow touched Earth during the July 21-22, 1990, solar eclipse. Despite the many satellites observing Earth each day, capturing the Moon's shadow crossing the Earth is still a relatively uncommon event. One reason is that satellite images are rarely snapshots anymore but are images created by scanning the Earth point by point. The fast-moving shadow often disappears off the disk before the satellite has had a chance to record the fleeting image. —*Sanjay Limaye, University of Wisconsin, Madison*

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ground that is warmer than the overlying atmosphere. Mars, they point out, has a similar situation (though considerably warmer) and it also develops dust devils that rise to heights of 6 kilometers.

The question of what powers the plumes has stumped planetary scientists ever since *Voyager 2* photographed them during the flyby in 1989. The best alternative model to the dust devil resembles more a terrestrial geyser. In this model, solar heating inside a few-meters-deep layer of transparent nitrogen ice creates a pocket of "hot" gas that finally breaks through the frozen surface and erupts.

Tryka and Ingersoll comment that clearer images of the surface at the feet of the plumes and of their structure would go a long way toward resolving the question. But until someone sends another probe to Neptune, those images won't be forthcoming.

Space News

BUDGET AXE SPARES CRAF/CASSINI

Planetary scientists breathed a collective sigh of relief last November. They had feared that funding for a pair of space probes, one to visit a comet and one to orbit Saturn, would be cut or drastically reduced. However, during last fall's Congressional budget debates, funding for the *Comet Rendezvous and Asteroid Flyby/Cassini* missions, considered the cornerstone of NASA's planetary program for the late 1990s, survived intact. (See "Voyages to the Worlds of Ice" in the December 1990 ASTRONOMY.)

During the budget battles, NASA's 1991 funding request was cut by $1.24 billion. While that sounds drastic, NASA's level of funding for 1991 is still 13.6% higher than it was for 1990, leaving NASA relatively unscathed compared to other federal agencies. The increase included an extra $30 million for the upgrade to *Hubble's* Wide Field/Planetary Camera. Some NASA progams were cut, however, among them $37 million for studies of eventual manned flights to the Moon and Mars, and $85 million for a space tug for use in low Earth orbit. Congress also cut $500 million from the 1991 allotment for the *Space Station*, prompting discussion among members of a White House/NASA review committee of a complete redesign of the *Space Station* and a possible 5-year delay in the first launches of station elements until a new unmanned heavy-lift launch vehicle can be developed.

NOVEL HUBBLE FIX PROPOSED

By sacrificing one of the *Hubble Space Telescope's* main instruments, astronomers feel they may be able to bring the remaining instruments up to full working capacity. The novel plan involves removing one of *Hubble's* five instruments, likely the High Speed Photometer. In its place in *Hubble's* instrument bay astronauts would install an optical system that would sharpen the light beam from *Hubble's* imperfect mirror before it enters three of the other instruments. This would allow the Faint Object Camera, the Faint Object Spectrograph, and the High-Resolution Spectrograph to perform to original expectations. A fourth instrument, the Wide Field/Planetary Camera, would be fitted with its own optical correction lens, as in the original fix-it plan. However, under the original plan, only the Wide Field/Planetary Camera would have been fixed, leaving the other cameras and spectrographs to peer through fuzzy eyes indefinitely. The new plan, which has the endorsement of the Space Telescope Science Institute, gives astronomers four fully-functional instruments, but at the cost of a complete loss of a fifth. The optical fixes are scheduled for a Shuttle mission in mid-1993.

ASTRO-1 LAUNCHED AFTER SIX-MONTH DELAY

For astronomers involved with the *Astro-1* mission, a $150 million ultraviolet and x-ray observatory, 1990 was a particularly trying year. From April to September, NASA tried four times to launch *Astro* and four times the launch was scrubbed at the last minute due to the orbiter *Columbia's* chronically leaky fuel system or other technical glitches. "One's enthusiasm certainly waxes and wanes," said Arthur D. Code, a University of Wisconsin-Madison astronomer and a principal investigator for one of *Astro's* telescopes. "How many times can you take it seriously and work on a crash program when history tells you you're wasting your time?"

The 10-day *Astro* mission called for observations of 524 objects ranging from comets and quasars to interstellar dust and gas. However, each delay spurred a frenzy of replanning. As the launch date changed, so did the *Astro* science plan as some objects, such as comets, faded from view and other targets slipped behind the Sun. "With any change, you gain some targets and lose some others," said Arthur F. Davidsen, a Johns Hopkins astronomer and principal investigator for *Astro's* Hopkins Ultraviolet Telescope (HUT). "Basically, all the delays are negative."

For example, in 1990 two bright comets — Austin and Levy — appeared in time to meet new launch windows, but they faded below peak brightness as *Astro* became the victim of technical problems with the Shuttle. The delay in early September 1990 meant astronomers lost Zeta Ophiuchi, a main sequence supergiant that is among the most luminous objects in the sky. Zeta Oph, said University of Wisconsin astronomer Kenneth H. Nordsieck, was to have been used by the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE) as a flashlight to illuminate the unusual spectral features of interstellar dust. "It's an example of an important object that we won't be able to see if we launch in the winter," Nordsieck said. "It's one of the few stars luminous enough to shine through the interstellar dust. There are some unidentified spectral features in the absorption of light by dust and getting a fix on them would have allowed us to find out what the dust is made of."

Not all the *Astro* news is bad, however. A silver lining to the most recent delay, according to Davidsen, is that a winter launch of *Astro* enables astronomers to look at the quasar 3C 273. "It's the most famous quasar and observations in the far and extreme ultraviolet might help us determine whether a black hole powers the quasar. This is a top priority for HUT," Davidsen said. "It's nice to have it back, but it's the only silver lining to the delays." *Astro-1 was finally launched December 1* and after some initial telescope pointing problems it returned excellent data.
— *Terry Devitt*

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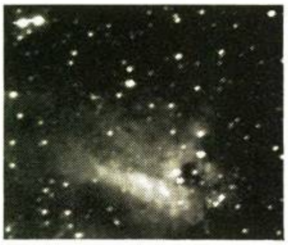

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Amateur News

A ROUNDUP OF REGIONAL STAR PARTIES

Oregon Star Party — The third annual Oregon Star Party, held August 18 to 20 in southeastern Oregon, had something for everyone — unless attendees were expecting comfortable summertime weather. The normally clear, dry skies at the 7,500-foot altitude site were replaced by cloudbursts of rain, hail, snow pellets, and lightning. The hard-core fanatics lied as persuasively as possible ("It's really clearing now!") to keep the party going, but on Saturday the more rational observers packed up and left in search of clearer skies and warmer beds.

Much to everyone's amazement, the sky *did* clear that night. Sunday night was even better. It was a night worth the 8-hour drive from Portland.

Despite the weather, everyone agreed the location near Fish Lake was excellent, if a bit remote. Even those who traveled farthest this year spoke of returning in 1991 for OSP #4. The tentative dates are September 6 to 8. — *Chuck Dethloff and Jim Reilly, Rose City Astronomers, Portland, Oregon*

Hidden Hollow '90 — From October 19 to 21, more than 250 amateurs from across the midwest converged on the Warren Rupp Observatory near Mansfield, Ohio. During the daytime, the program consisted of talks by comet-hunter David Levy, astrophotographers Don Parker and Jack Newton, and author/scientist Stephen Edberg. The Association of Lunar and Planetary Observers presented David Levy with the Walter H. Haas Award in recognition of Levy's achievements in solar system observing, notably his six comet discoveries.

A high point of the convention was the spectacular skies on Friday night. High daytime clouds cleared at sunset to reward observers with excellent views of the white spot on Saturn through the 31-inch f/7 Newtonian at Warren Rupp and of deep-sky objects through the fifty telescopes brought by amateurs.

With the help of Don Parker's CCD video camera, everyone was able to see a live view of Mars through the 31-inch on a television monitor, with Parker providing running commentary on the Martian features. Jack Newton was also able to demonstrate the operation of a Santa Barbara Instrument Group CCD camera.

A Hidden Hollow tradition continued this year when Tom "Biff Smooter" Burns, astronomy columnist for *The Columbus Dispatch*, presented his tongue-in-cheek talk. This year's topic was "Wavefront Correction Techniques for Space Borne Data Collection Platforms, or Just Give Me a Pitch Lap and a Spacesuit and I'll Fix the Dang Thing Myself!" Biff's ... er, Tom's talk has become one of the most popular events at Hidden Hollow. — *Robert Bunge*

TELESCOPES OF ALL SIZES graced the field at this year's Deep South Regional Star Gaze. Photo by Mike Porcellino.

Deep South Regional Star Gaze — First held in 1983, this lively event draws people from Louisiana, Mississippi, and Alabama. "The people who come out here are a real mix of amateurs, and they come here to observe," said Mark Stauffer, president of the Baton Rouge Astronomical Society, this year's host group. "Some people are dedicated observers pursuing serious programs while others are here to relax and enjoy the sky," Mark added. "I came out here because my son thought it would be fun," one attendee told me. "He was right, this whole weekend has been fun."

Percy Quin State Park south of McComb, Mississippi, has been the site for the Deep South Star Gaze since its inception. This year, the event began on Thursday, October 18. The evening was clear and steady, with scopes quickly turning to Saturn and its spot.

On Friday night, the *Hubble Space Telescope* was scheduled to pass over the site at 7:30 p.m. Cameras were loaded, and shutters were primed. Right on time, there was *HST*, majestically moving through Sagittarius. By Saturday evening, 125 people and 60 telescopes covered the field. Folks without scopes set up lawn chairs and spread blankets on the ground and gazed at the starry dome.

One of the things I was most impressed with this year was the large number of youngsters present. By bringing newcomers to the hobby, the organizing groups are helping to ensure they will have a growing base for continued growth and success.

The 1991 Star Gaze will be held at Percy Quin State Park from November 7 to 10. —*Mike Porcellino*

OBSERVE WITH HST

In recognition of their contribution to the science of astronomy, amateur astronomers have been awarded a percentage of the observing time on the *Hubble Space Telescope*. Five amateurs were granted time from the first batch of proposals received prior to *HST's* launch. *HST's* Amateur Astronomers Working Group is now seeking proposals as part of a second round search. The deadline for submitting proposals for this new round has been extended to May 31, 1991.

Guidelines for submission can be obtained from the American Association of Variable Star Observers, 25 Birch Street, Cambridge, MA 02138. Completed proposals should be submitted to the same address. □

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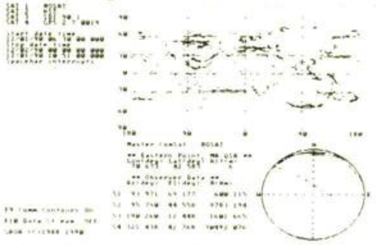

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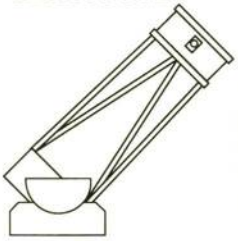

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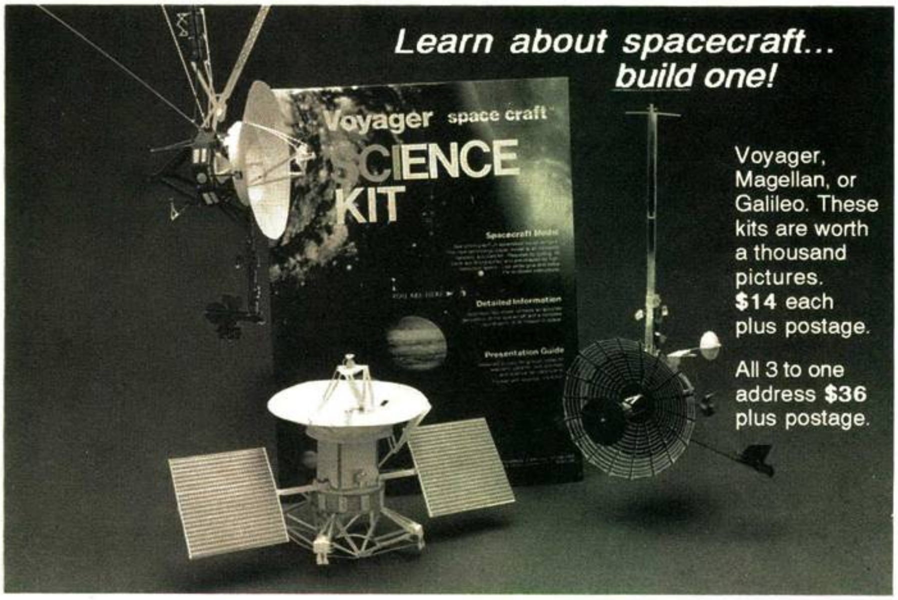

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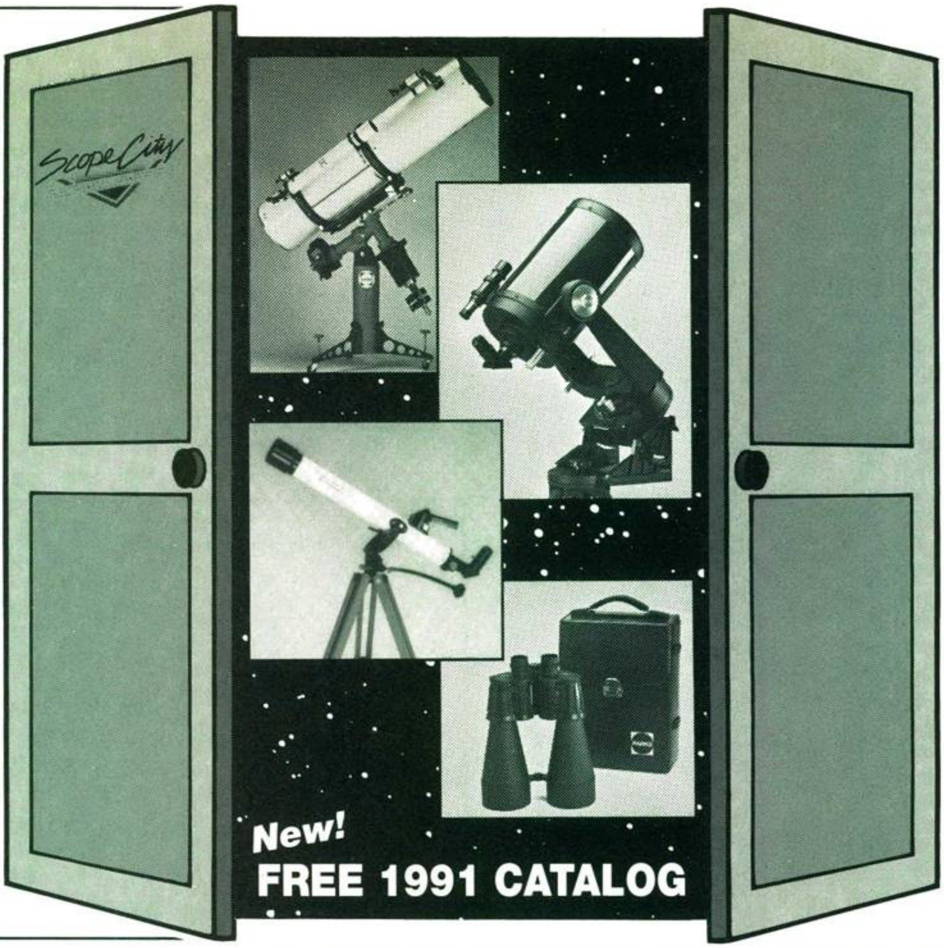

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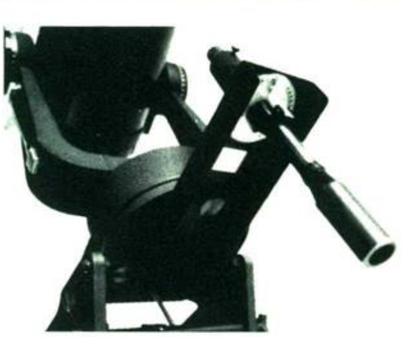

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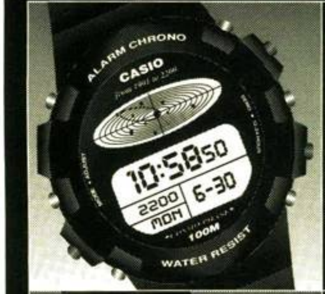

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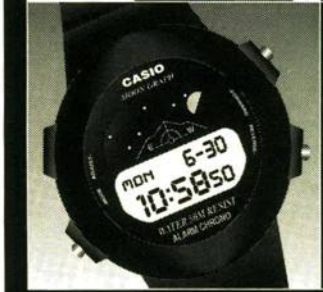

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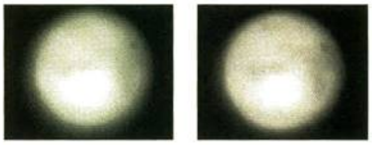

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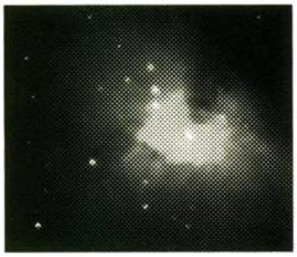

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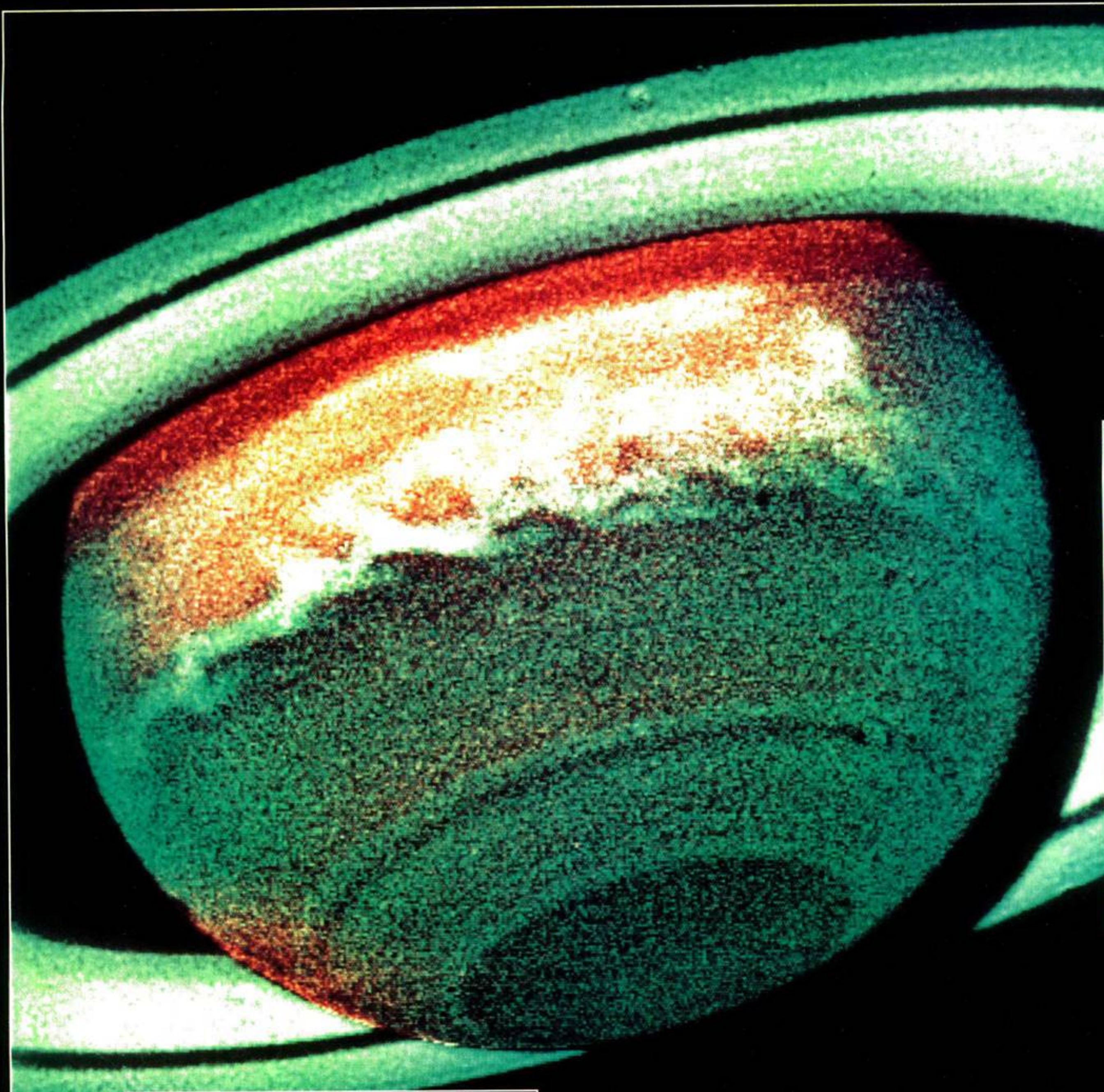
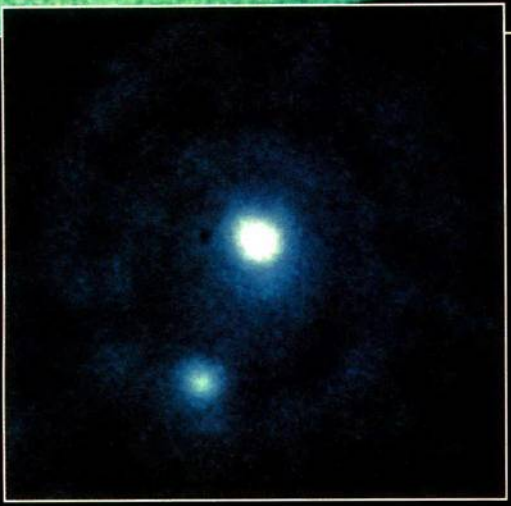


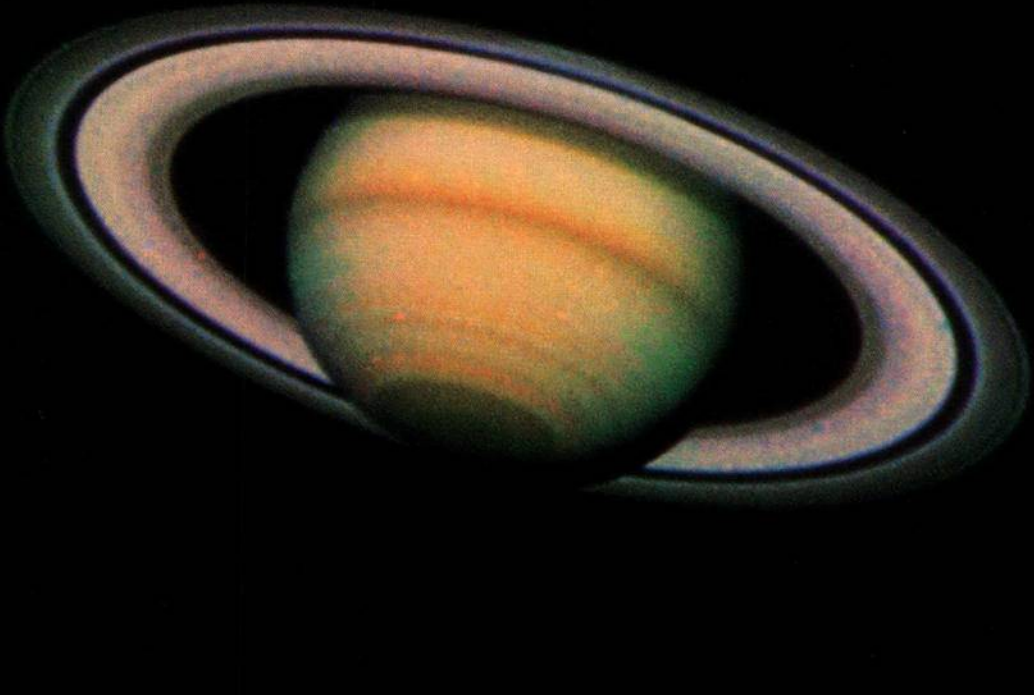


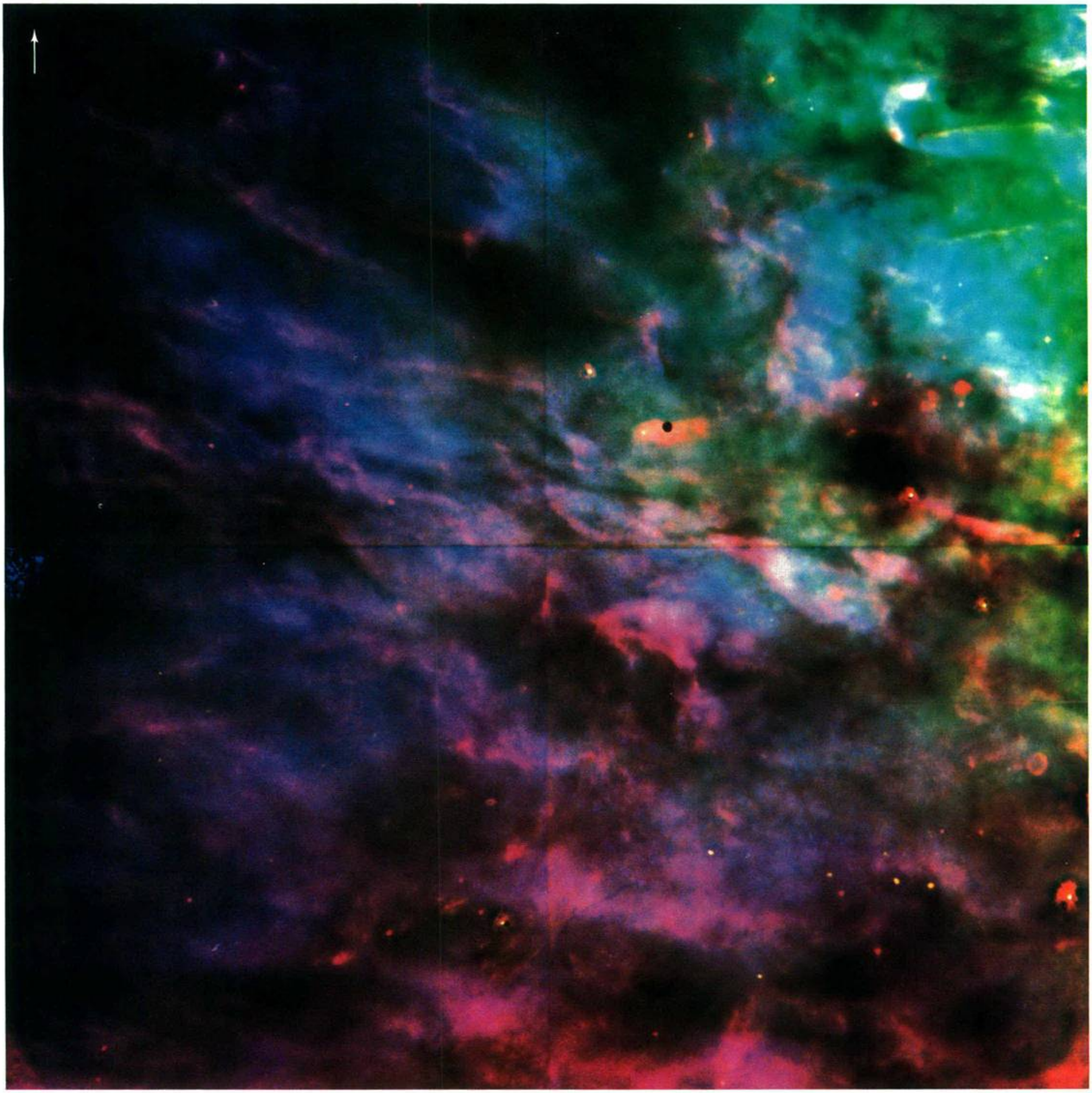
HUBBLE REVEALS the solar system with unprecedented clarity. Saturn's Great White Spot (above), north polar hood (above right), and ring system (right), all appear sharper than they do to Earth-based telescopes. NASA images. Meanwhile, HST images Pluto separate from Charon (left) for the first time. NASA/ESA image.

Hubble Opens New Vistas

Astronomers assessing HST's capabilities are cautiously optimistic that the telescope will return big dividends.

by Richard Talcott





Devastated. That word, perhaps more than any other, summed up the feelings of astronomers, mission planners, and millions of Americans when they learned of the *Hubble Space Telescope's* major optical flaw. The hopes and aspirations of a generation of astronomers, not to mention decades of planning and more than a billion dollars in taxpayers' money, had gone into the project, and it all seemed in jeopardy.

The widespread depression that followed the news of the primary mirror's spherical aberration has now eased somewhat, however. No, there are no quick or easy fixes to the telescope's optical problem. But instead of focusing on what *HST* can't do, astronomers are now concentrating on what the telescope *can* do. And that turns out to be plenty.

This past summer and fall, mission planners put the two imaging instruments on *HST* — the Wide-Field/Planetary Camera, or WF/PC (pronounced wiff-pick) for short, and the Faint Object Camera — through their paces. The resulting series of images proved that *HST* can do forefront astronomical research, most of it impossible to do from the ground, despite the flawed mirror. Although many exciting observations will have to be postponed until after a shuttle mission in 1993, there will be no lack of exciting results during the next few years.

Assessing the Problem

No one ever expected *HST's* primary mirror to be flawed to the extent that it is, and there were no contingency plans for coping with such an error. Add to that the fact

WISPS OF NEBULOSITY appear like a rippling window curtain in this *HST* image of the Orion Nebula (left). NASA image. The area photographed by HST was just a small part of the whole nebula (above, with HST camera frame superimposed). Photo by Gérard Therin.

that each planned observation is affected differently by the aberration, and you can see why the various science teams had to re-evaluate their programs.

Some observations remain largely unscathed by the spherical aberration and will be carried out with few or no changes. Other proposals are so severely affected that they won't be viable until *HST* is repaired. But a large percentage of the planned observations falls somewhere in between the two extremes — they can still be performed with the telescope in its aberrated state, but they require some type of modification, such as longer exposure times.

To help the science teams learn what can be done with *HST* and what changes might need to be made to their scientific programs, the Space Telescope Science Institute decided to implement a "Science Assessment Program." Each instrument was to observe a wide variety of mundane objects to see how well *HST* handled them. It's much like looking at the tip of an iceberg — although the program misses many potentially interesting objects, the knowledge it gives the science teams on how *HST* performs on familiar subjects will be invaluable later on when the telescope is pointed at more exotic objects.

The Wide-Field/Planetary Camera and Faint Object Camera were the first instruments to be thoroughly assessed. That process began last summer and lasted through much of the fall. Assessing the High Speed Photometer and the two spectrographs on *HST* began in the fall and is continuing this winter. But it is the results from the imaging cameras that have created the most excitement so far.

A View of Distant Neighbors

A long-anticipated target for *Hubble* was the planet Pluto and its large satellite, Charon. And the members of the Faint Object Camera science team didn't disappoint. They made Pluto the first solar system object to be observed by *HST*.

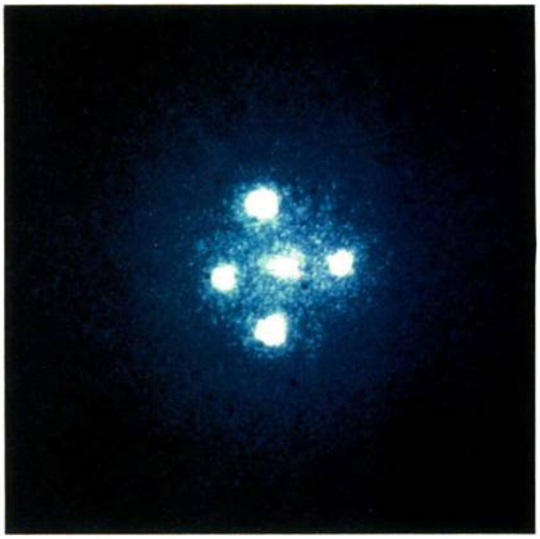
Pluto is difficult to study from Earth because it is so small and distant. Smaller than Earth's Moon and located far across the solar system, Pluto never appears as more than a faint point of light to ground-based observers. And Pluto is the only planet in the solar system that has not yet been visited by spacecraft.

Despite the difficulties in observing Pluto from Earth, Charon first came to light through ground-based observations. Discovered by James Christy in 1978 as a small bump projecting from Pluto's image on a photograph, Charon turned out to be remarkably big. It is about half the size of Pluto, making the Pluto-Charon system more of a double planet than a planet and satellite.

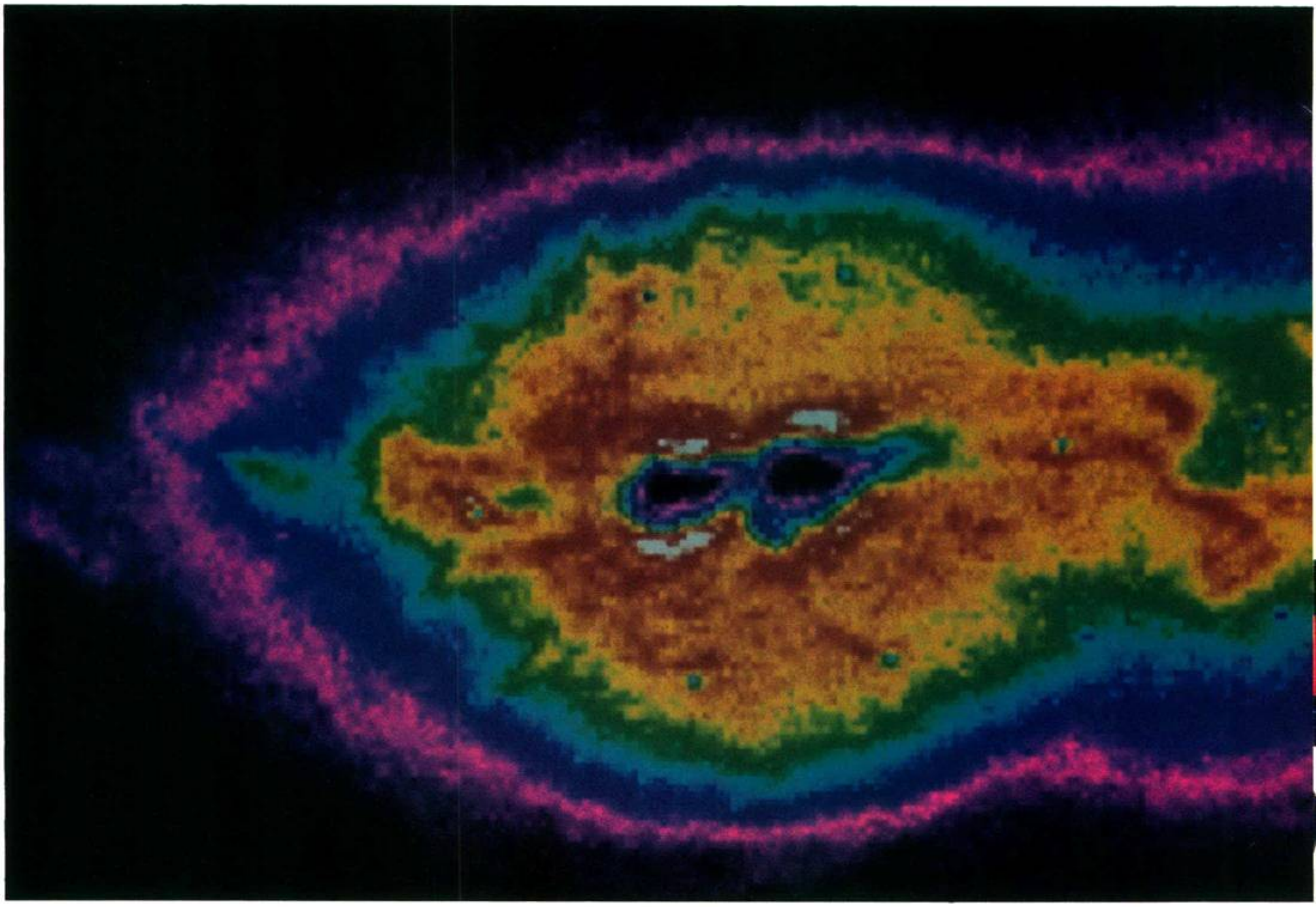
Nevertheless, Pluto and Charon had never appeared truly distinct on a photograph until they were photographed with the Faint Object Camera (see page 30). *HST* clearly split the two objects, which were separated by only 0.8 arcsecond — about the maximum possible — at the time of the exposure. Pluto appears much brighter than Charon for two reasons: it is about twice as large as Charon and it appears to be covered with methane ice or snow, which reflects more sunlight than the water ice that covers Charon.

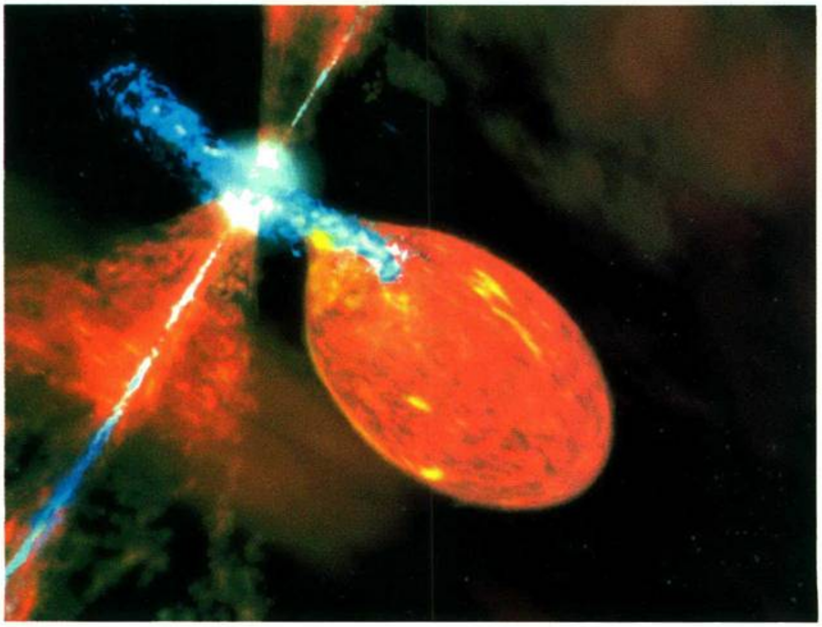
The *HST* image of Pluto also marks the first time the telescope took a long time exposure of a moving object. Unlike the much more distant stars and galaxies, planets move across the sky, and it's a tricky task to program the orbiting observatory to accurately track this motion.

Another obvious feature in the image is the primary mirror's spherical aberration. It causes the circular halo around Pluto that nearly passes through Charon. The aberration makes seeing any surface details on



THE EINSTEIN CROSS consists of four images of a single distant quasar surrounding a foreground galaxy that acts as a gravitational lens. NASA/ESA image.





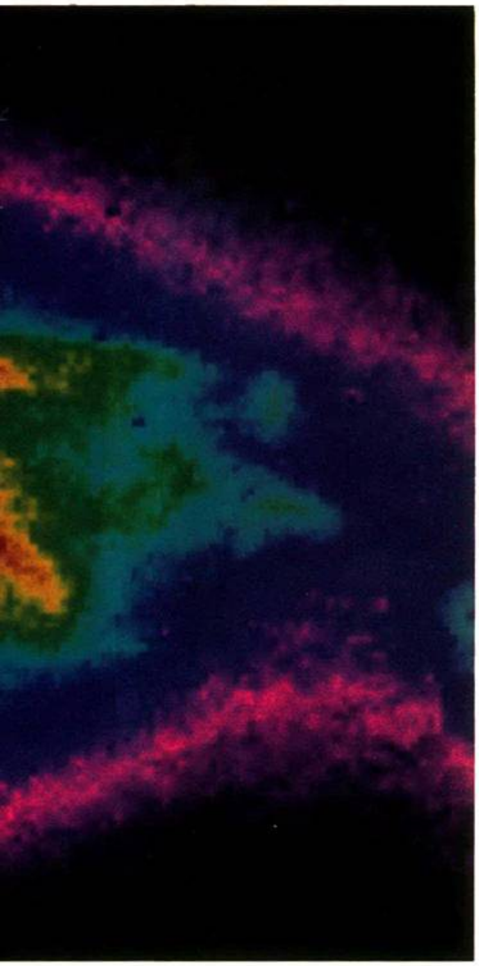
GAS SHOOTS OUT from the core of R Aquarii along magnetic-field lines (above). Image courtesy Francesco Paresce. The recurrent nova apparently explodes when matter from a red giant builds up on a white dwarf (left). Illustration by Dana Berry.

Pluto or Charon impossible at this stage, though future high-resolution images and detailed analysis may reveal some of these elusive features.

The Faint Object Camera team wasn't the only group to target a solar system object. The WF/PC team went after an even bigger prize — Saturn. The first image taken of Saturn (which appeared on the cover of the December 1990 issue of ASTRONOMY), showed details never before captured on ground-based photographs, though such details have been seen by trained observers at the eyepiece of a telescope. A closeup of the north polar region of the planet (page 31) shows atmospheric features, including an unusual hexagon-shaped structure. The details visible in the *HST* photos of Saturn are what you would see with the naked eye if Saturn were twice as far away as the Moon (which would make the planet a behemoth, measuring over 7° across!)

Saturn also was the subject for the first "target of opportunity" of the mission. Although *Hubble's* observing schedule is normally fixed weeks, if not months, in advance, the telescope can target objects of special interest on fairly short notice.

Such a situation arose in late Sep-



tember, when a large white spot appeared on Saturn's surface. This was the first large-scale atmospheric eruption on the planet in the past 60 years, and astronomers wanted to observe it with the sharp eye of *Hubble*. They got that opportunity in early November (see page 30). The *HST* images allowed researchers to study the motions and vertical growth of the cloud in unprecedented detail, a key step to understanding what triggers these atmospheric events.

Scouting the Galaxy

With a limited number of targets and the difficulties in tracking moving objects, it's no wonder that most of the Science Assessment Program involved objects beyond our solar system. One of the more intriguing of these objects was the symbiotic nova known as R Aquarii, which appears to be expelling gas at a prodigious rate. It seems only fitting that the man who *HST* is named for, Edwin Hubble, observed this object intensively in the 1930s and 1940s.

R Aquarii is of interest for several reasons. First, because the nova has exploded more than once in the past, it may well explode in the future, and astronomers want to learn what triggers this process. Second, at a distance of 700 light-years R Aquarii is one of the closest of this class of star, and so it can be studied in much more detail than other similar stars.

Novae are thought to occur in close binary systems consisting of an old star that has lost its outer layers and become a white dwarf, and a younger star that has evolved into a red giant. As gas flows from the red giant to the white dwarf, it builds up on the white dwarf's surface. Eventually, enough gas collects to ignite, creating a titanic explosion that can be seen across much of the Galaxy.

Much of the outer layers of the star are ejected during the explosion at speeds of up to a few hundred thousand miles per hour. This is one of the few ways that elements heavier than helium are dispersed into space, where they could possibly be incorporated into future planets or people. Although supernovae, with their even larger explosions, also play an important role in this process, novae occur about 1,000 times more frequently.

The highly detailed image of R Aquarii returned by the Faint Object Camera shows a remarkable amount of activity (opposite page). The image, taken in the light of doubly ionized oxygen, shows two dark knots at the center. These are actually bright areas (magnitude 10.2 at the time of the observation) that appear dark because of saturation effects in the detector. The binary system itself lies hidden in one of these areas.

But the most fascinating features of this image are the rapidly moving filaments of gas that surround R Aquarii. This ionized material shoots out of the core and is then channeled by the strong magnetic fields present. This outflow of material is easier to see toward the right of the image than toward the left. In one spot, the material seems to detour around an obstruction in the flow's path. No one has yet developed a good explanation for this unusual flow pattern.

While R Aquarii is a star system near the end of its life, the Orion Nebula is a stellar nursery. And an early *Hubble* image of this nursery shows fine-scale structure down to the limit of what the telescope can see (page 32).

The area under scrutiny is a thin sheet of gas at the boundary between the hot, inner part of the nebula and a cooler, denser, neighboring cloud. The sheet — which reminds some astronomers of a rippled window curtain — glows from light emitted by gaseous sulfur atoms and is color-coded red in the photo. The blues and greens at the bottom right of the image represent emission from gaseous oxygen and hydrogen, respectively, and represent the outer edge of the nebula's hot interior.

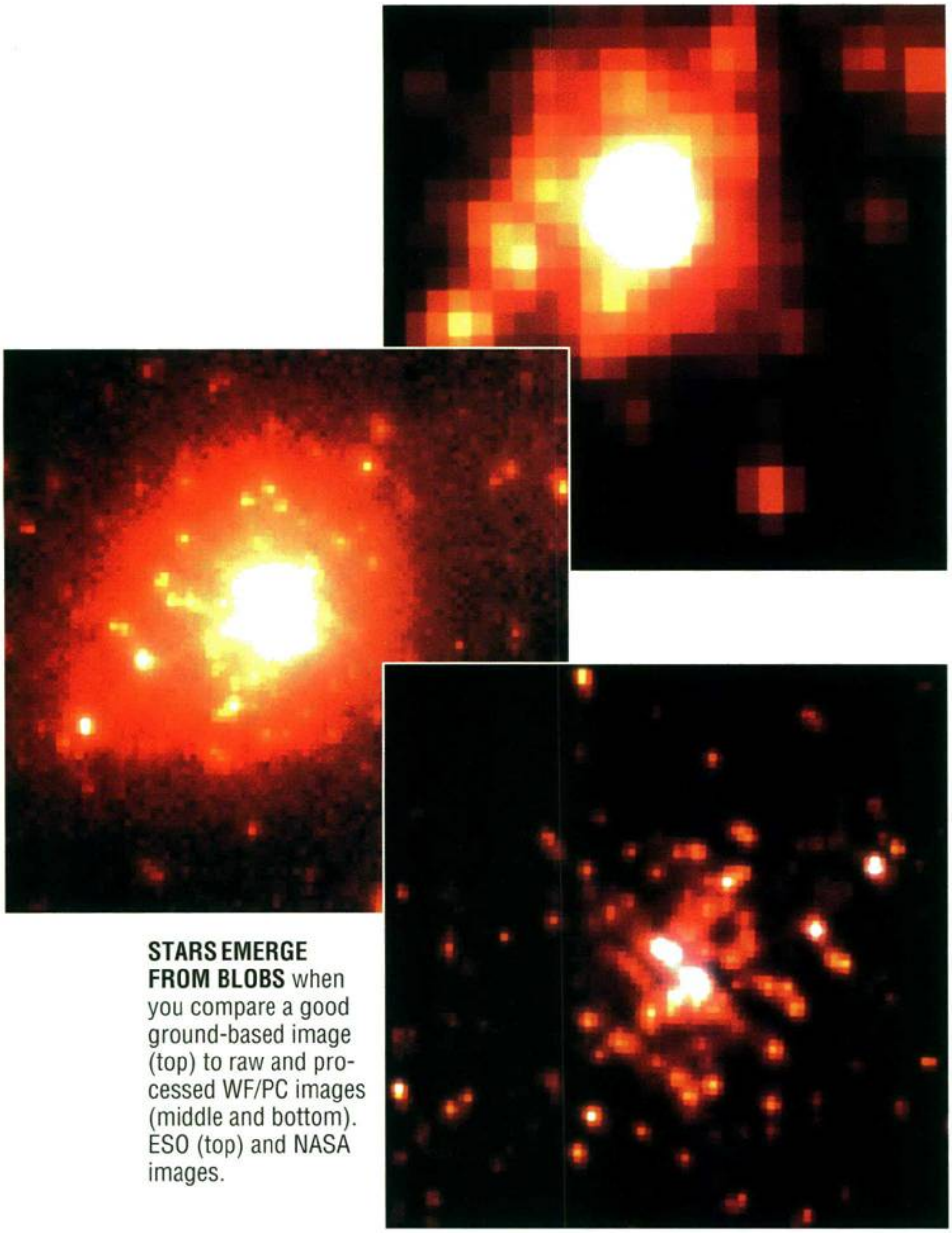
The inner regions of the Orion Nebula are littered with newborn and young stars that have recently formed out of the nebular gas and dust. Many of these stars are very hot and radiate a tremendous amount of ultraviolet radiation, which stimulates the gas in the nebula to emit light. But the intense bombardment of ultraviolet radiation also erodes the edges of the cool, dense, surrounding nebula. That's where the thin sheet photographed by *HST* lies — at the eroding edge of the dense gas cloud. That boundary will continue to expand outward, and the region where the thin sheet now resides will be claimed one day by the hot interior.

Exploring the Great Beyond

One of the original objectives for HST was to resolve structure at the centers of distant galaxies. The results of the Science Assessment Program show that that goal may still be met.

One of the early targets for the WF/PC was the nucleus of the Seyfert galaxy M77. Astronomers suspect that the high luminosity characteristic of Seyfert galaxies is gener-

NOT AS NORMAL as thought, the galaxy NGC 7457 reveals an unexpectedly high concentration of stars at its core to *HST's* penetrating eye. NASA image.



STARS EMERGE FROM BLOBS when you compare a good ground-based image (top) to raw and processed WF/PC images (middle and bottom). ESO (top) and NASA images.

ated by a black hole lurking at the center of the galaxy. For M77, the black hole would have to have a mass 100 million times that of the Sun to generate the galaxy's observed luminosity.

The WF/PC image of M77 reveals several clouds of ionized gas near the center of the galaxy (page 37). These clouds are glowing because they are ionized, presumably by radiation emanating from the black hole in the form of a jet. The astronomers liken the glowing clouds to a moth caught flying through a flashlight beam on a summer's night — when the beamlike jet hits and ionizes a cloud of interstellar gas, the gas begins to glow.

A more visual example of a galactic jet comes from the powerful radio galaxy PKS 0521–36, which lies roughly 1 billion light-years from Earth. This is one of only a few galaxies that possesses both a radio and an optical jet, both of which are produced by the synchrotron process in which electrons are accelerated to near the speed of light. Astronomers hope that by studying jets at a variety of wavelengths they'll better understand these energetic structures.

Astronomers subtracted the galaxy's bright nucleus from the Faint Object Camera's image of PKS 0521–36 to more clearly show the 30,000-light-year-long optical jet (page 37). The image also reveals a "hot spot" near the nucleus that had not been seen before, either at radio or optical wavelengths.

Another target for *HST*'s Faint Object Camera was the gravitational lens G2237+0305, which is also known as the Einstein Cross (page 33). The *HST* image of the Einstein Cross is much sharper than any ground-based image of the object. The Einstein Cross consists of a distant quasar that lies directly behind a spiral galaxy whose gravity acts as a lens to bend the light of the quasar. The net result is that four separate images of the quasar are formed around the intervening galaxy.

In this case, the galaxy that does the lensing is relatively close, only 400 million light-years away; the quasar, on the other hand, is 20 times farther out, or 8 billion light-years away. Astronomers hope that with further analysis they'll be able to determine the positions of the objects more precisely and discern details in the intervening galaxy.

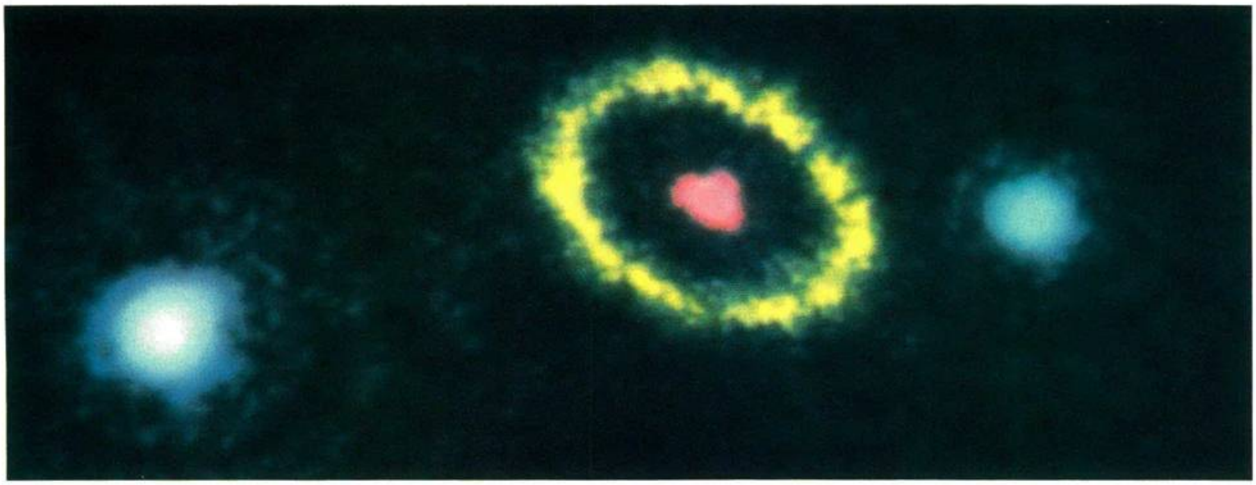
Fixing the Fuzziness

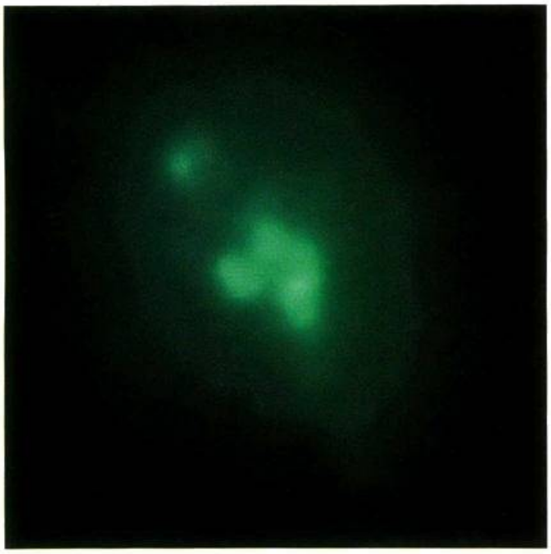
The closest galaxy to the Milky Way — the Large Magellanic Cloud — also held several good targets for *HST*. And two of the more successful observations during the Scientific Assessment Program were of objects in the Large Magellanic Cloud: supernova 1987A and the R136 star cluster at the center of the Tarantula Nebula.

The Faint Object Camera captured the elliptical ring that surrounds supernova 1987A (page 37) to a resolution of 0.1 arcsecond — far better than ground-based telescopes can do. Even though this is a raw image — one look at the halos around the two field stars will convince you of that — details in the ring are visible.

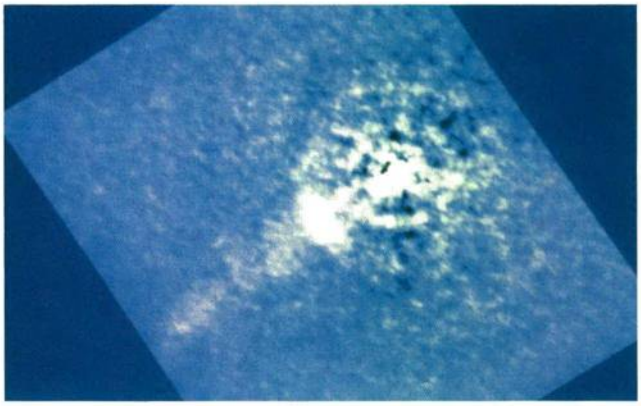
But image processing has played, and will continue to play, a big role in images from *HST*'s cameras. The goal in most instances is to end up with an image that is as close to what the telescope would have given you if it were perfect. In some cases, that isn't quite as hard as it at first might seem.

For example, if you photograph a star with *HST*, you'll end up with an image that shows a bright core surrounded by a large, diffuse halo — the classic shape expected from a mirror with spherical aberration. If you can mathematically describe the shape of the flawed image produced by the telescope when it looks at a star, you can invert the process and mathematically describe what the star must have looked like given the shape of the flawed image. This technique is called deconvolution, and it works beautifully in some in-





A RING OF GLOWING GAS surrounds the luminous center (in red) of supernova 1987A (above). NASA/ESA image. Clouds of ionized gas lie at the core of the Seyfert galaxy M77 (below left). NASA image. A jet of plasma bursts forth from PKS 0521–36 (below right), a rare radio galaxy that has both a radio and an optical jet. NASA/ESA image.



stances. Deconvolution works especially well, as you might guess, when the target is a star or a star cluster and is reasonably bright. It is not as successful or easy to do, however, when the target is an extended object or faint.

You can see vividly the effects of deconvolution on the images of the R136 star cluster taken with the WF/PC (opposite page). At top is a ground-based image taken under exceptional observing conditions: the star images measure just 0.6 arcsecond across. The unprocessed WF/PC image (middle) shows many more stars than the ground-based image because the apparent stellar diameters measure just 0.1 arcsecond across. Still, there are disconcerting halos around the stars caused by the spherical aberration. When that image has been deconvolved (bottom), the image is even sharper and even more stars become visible.

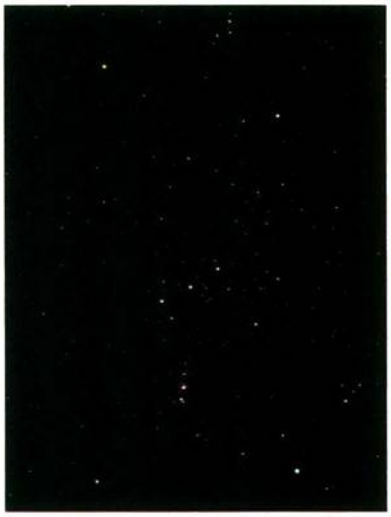
In the past, some astronomers thought that R136 contained a handful of supermassive stars — stars a few hundred times more massive than the Sun or larger. That now appears unlikely, because each of the blobs that astronomers thought were the supermassive stars have been shown by *HST* to be a group of several smaller stars. That doesn't take anything away from this cluster, however. R136 boasts at least 20 hot, young, and massive stars within a diameter of just 1.6 light-years!

What Does the Future Hold?

The Scientific Assessment Program for the WF/PC and Faint Object Camera has shown that *HST* can accomplish lots of important astronomy in its present state. But there are also many areas where the cameras will fall far below expectations. The spherical aberration makes imaging faint objects difficult if not impossible, and looking at faint objects on the edge of the universe was one of *HST's* most exciting projects.

The biggest loss for now, however, is the effort to measure the Hubble constant, the rate at which the universe is expanding. This was one of the three key projects scheduled for *HST*, but it now has to wait until the new Wide Field/Planetary Camera, WF/PC II, is installed by shuttle astronauts in 1993. *Hubble* needs to observe and measure the brightnesses of 24th-magnitude and fainter stars in distant galaxies to determine the Hubble constant, and that's just about the point where the spherical aberration makes measuring stellar brightnesses nearly impossible.

During the winter months, the Scientific Assessment Program for the photometer and spectrometers will continue and some scientific projects will get under way. Other astronomers will be re-evaluating their proposals, based on the results of the Scientific Assessment Program, to see whether and how they can make them work. And throughout it all, *HST* will keep orbiting Earth and doing as it's told, sending down data to astronomers hoping to unlock a secret of the universe. □



STELLAR ASTRONOMY

Regal Rigel

Rigel is far more than the brightest star in Orion. It's also one of the biggest, hottest, and most luminous stars in the Galaxy.

by Peter Jedicke and David H. Levy

No where in the heavens is there a constellation more recognizable than the mighty warrior Orion. And with seven stars shining at 2nd magnitude or brighter, Orion features more bright stars than any other constellation. The Hunter's eastern shoulder, Betelgeuse, contrasts with the rest because of its ruddy hue. The other six stars all shine with a brilliant diamond-blue color: the western shoulder Bellatrix; the belt stars Alnilam, Alnitak, and Mintaka; and the two knees, Saiph and the brightest of them all, Rigel.

Stars like Rigel and the other bright blue stars in Orion dominate the night because they represent the sky's best compromise between rarity and superlative. Less than one star in a thousand is as hot and luminous as Rigel, but they are easily visible across a thousand light-years of space. Although there are marginally brighter stars, they are too few to look impressive as a group. And cooler stars, of which there are legion, literally pale in comparison. You won't find a single Rigel-type star among the three hundred stars nearest to Earth, but there are a dozen or more among the three hundred brightest.

Nature may have been reluctant to encourage the formation of Rigel and his brethren because they require so much more mass than the Sun or dimmer stars. Rigel is a huge star: as much as 25 solar masses contained in a sphere that stretches across 65 times the Sun's diameter. In our Sun's place, Rigel would almost fill the orbit of Mercury. Although this is not nearly as large as the bloated orbs of the red supergiants like Betelgeuse, Rigel is far denser, hotter, and more spendthrifty with its nuclear fuel reserves. There's a lot more excitement among the hot blue supergiants than among the cool reds.

Rigel and its neighbors appear blue-white because their surfaces are extremely hot. A star's color is a direct result of how hot its surface is, with hotter stars emitting more of their light at shorter (bluer) wavelengths. The temperature at the surface of Rigel is nearly 10,000 kelvins, which is about twice as hot as the Sun's yellow surface and three times the surface temperature of ruddy Betelgeuse.

Rigel's high temperature implies tremendous brightness as well. Each square inch of Rigel's surface radiates some fifteen times the energy of each square inch of the Sun's surface and nearly one hundred times the energy of each square inch of Betelgeuse. This profligate rate of energy generation makes Rigel bright, but it also raises an interesting question — why doesn't Rigel appear even brighter?

A Star of Superlatives

The brightness of any star depends on two factors: its luminosity and its distance. The Sun is so bright simply because it is so close — if it were as far away as some of the nearer stars it would appear unimpressive. Sirius, the brightest star in the sky, is somewhat more luminous than the Sun but is bright largely because it lies only nine light-years from Earth. Rigel and the other blue stars in Orion are all a thousand — and some more than two thousand — light-years away, lonely lanterns shining down a long cosmic tunnel. Even Betelgeuse, at 650 light-years' distance vastly farther than Sirius, is a heavenly neighbor compared to Rigel and the blue stars of Orion.

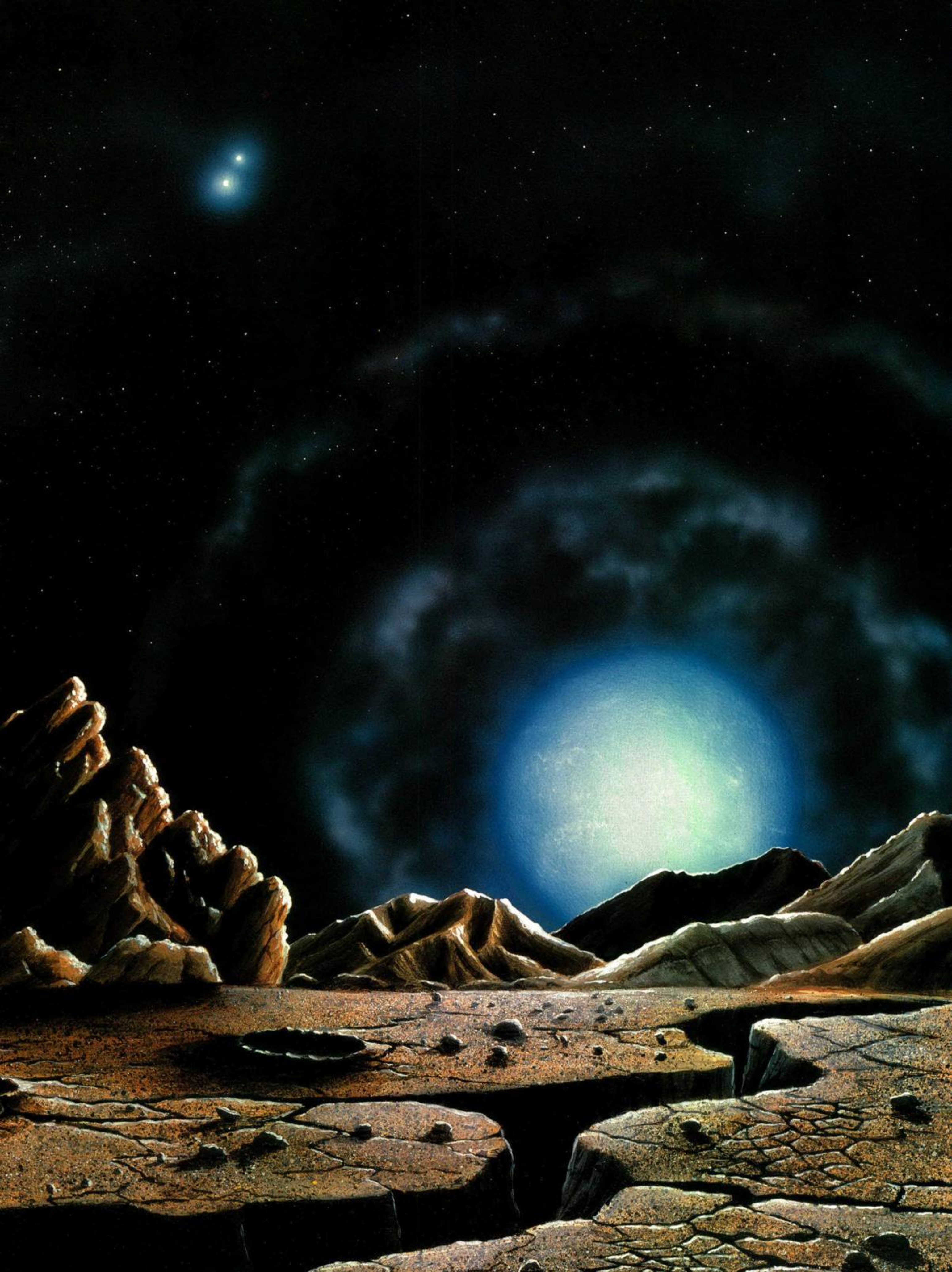
Astronomers determine a star's intrinsic brightness from its spectrum. By scrutinizing thousands of stellar spectra over the past century, astronomers have categorized stars into various types, each of which have a distinct luminosity. Rigel belongs to spectral class B8, which means it shows features characteristic of neutral hydrogen. Further, the sharpness of these spectral features indicates that Rigel is a brilliant supergiant of what is called luminosity class Ia. These two ways of categorizing stars give astronomers a remarkably reliable measure of the luminosity of any star, even if its distance is not known beforehand.

For Rigel, its spectrum reveals a star whose luminosity is some 50,000 times that of the Sun. That means if Rigel were only 10 parsecs (32.6 light-years) from Earth — a standard distance astronomers use to compare stellar brightnesses — it would shine at magnitude –7.1. At the same distance, the Sun would shine weakly at magnitude 4.8 and appear as a faint naked-eye star.

Not only is Rigel different from the Sun on the outside, but the two stars are different beneath the surface as well. Rigel's tremendous luminosity originates in the star's interior, where the temperature reaches an incredible 100 million kelvins. (In contrast, the Sun's internal temperature is a rather modest 15 million kelvins.)

This temperature difference causes Rigel to be

RIGEL BLASTS the tortured surface of a nearby planet with intense radiation. In the distance, two companion stars shine brightly. All illustrations by MariLynn Flynn.



powered by a different set of nuclear reactions than is the Sun. Whereas most of the Sun's energy comes from protons fusing together to form helium via the proton-proton chain, Rigel's superhot interior generates much more energy by fusing three helium nuclei into one carbon nucleus in the triple-alpha process. The Sun is just not hot enough to take advantage of the more powerful reactions that fuel Rigel's high luminosity.

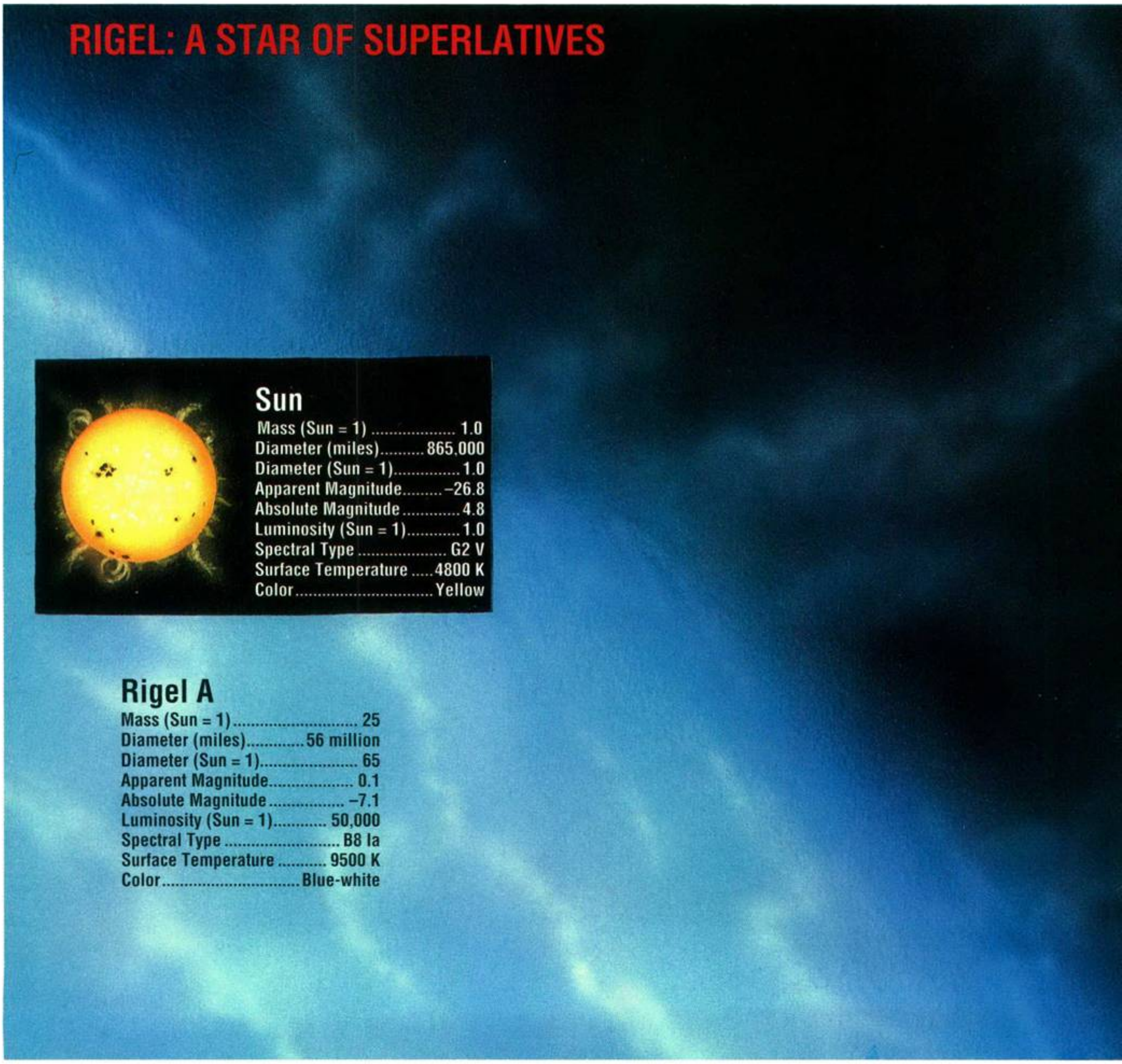
Rigel's interior differs from the Sun's in one other fundamental way. The temperature drops much faster as you move away from the center of Rigel than it does as you move out from the center of the Sun. This temperature drop is so steep in the inner parts of Rigel that energy is transported by moving currents of hot gas. Called convection, this process carries heat out of Rigel's interior very efficiently. Farther from Rigel's center the temperature changes more slowly, and energy is transported by electromagnetic radiation instead. In the Sun, on the other hand, the situation is reversed — energy is transported by radiation in the interior while convection dominates in the outer layers.

More than Meets the Eye

When we observe Rigel with a telescope, the hot blue supergiant is not all that greets us. Rigel is a system of at least three stars whose nature has fooled some of the great observers. The intriguing story of Rigel's multiplicity began in the 1830s, when double-star observer F. G. W. Struve first saw a companion to Rigel. The companion, designated Rigel B, appeared 9.5 arcseconds away from Rigel itself, which corresponds to a separation of about 2,500 AU at Rigel's distance. The companion has the same B8 spectral type as the primary star Rigel A, but is a main-sequence star and thus much smaller and fainter than Rigel.

Since Struve's original measurements, however, no one has reliably observed any change in the relative positions of Rigel A and B. Nevertheless, the two

RIGEL: A STAR OF SUPERLATIVES



Sun

Mass (Sun = 1)	1.0
Diameter (miles)	865,000
Diameter (Sun = 1)	1.0
Apparent Magnitude	–26.8
Absolute Magnitude	4.8
Luminosity (Sun = 1)	1.0
Spectral Type	G2 V
Surface Temperature	4800 K
Color	Yellow

Rigel A

Mass (Sun = 1)	25
Diameter (miles)	56 million
Diameter (Sun = 1)	65
Apparent Magnitude	0.1
Absolute Magnitude	–7.1
Luminosity (Sun = 1)	50,000
Spectral Type	B8 Ia
Surface Temperature	9500 K
Color	Blue-white

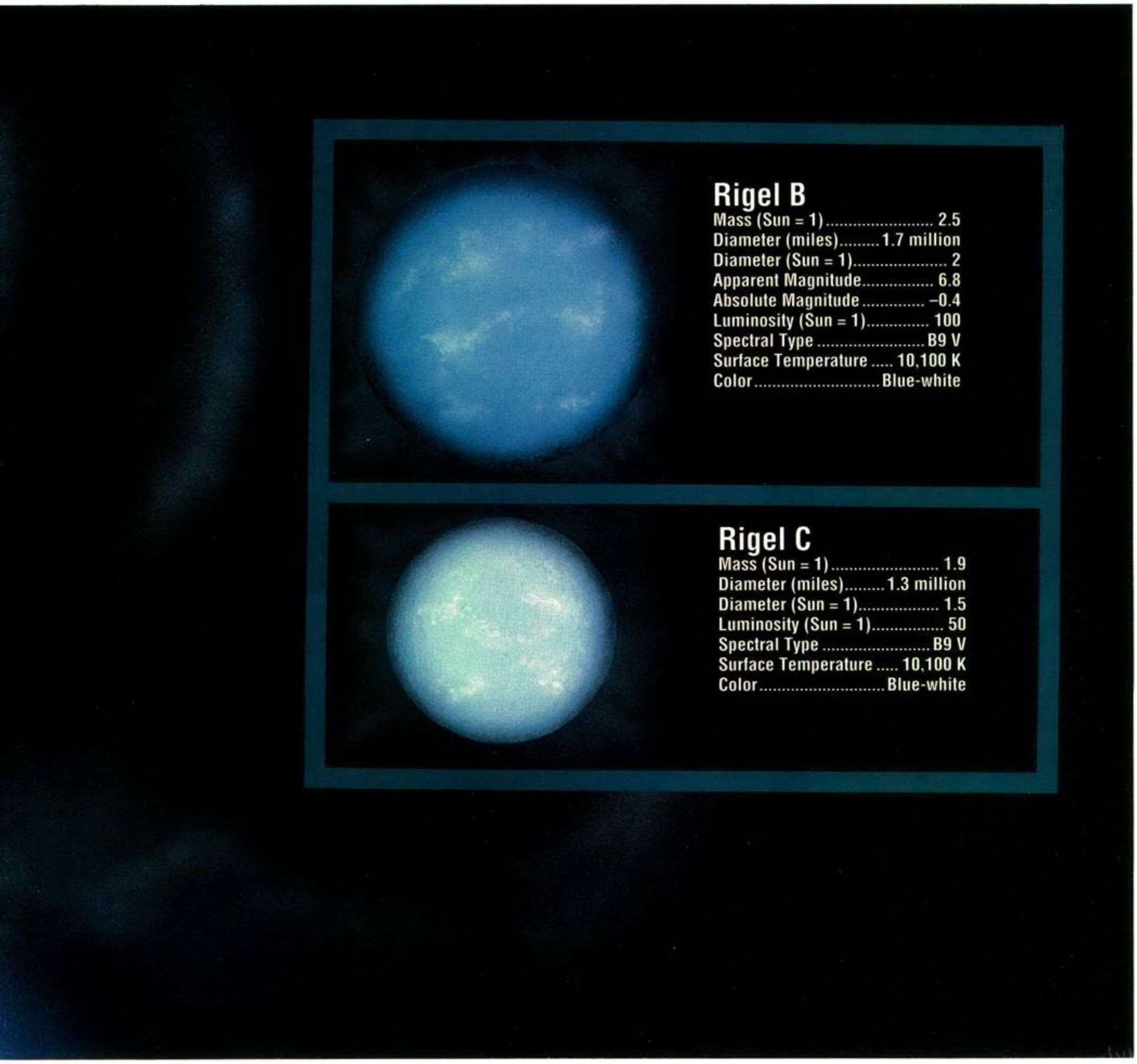
stars have nearly identical proper motions — meaning their apparent motions across the sky are the same — and velocities along our line of sight. It is highly unlikely that their common motion through space is a coincidence, so astronomers presume that the pair is physically related and that Rigel A and B do orbit each other, albeit very slowly.

The Rigel system apparently gained another member in 1908, when the Canadian astronomer John Stanley Plaskett reported that Rigel A was itself a spectroscopic binary. He inferred this from spectra of Rigel that seemed to show regular variations in the star's radial velocity. Radial velocity is the speed of an object in the direction either toward or away from an observer. When a star moves along our line of sight, the wavelength of the light we receive from it is shifted by an amount proportional to the star's radial velocity. If the star is moving toward us, the light is shifted toward shorter wavelengths, and when the star moves away from us the light shifts to longer wavelengths.

A star in orbit around a companion star will seem to move alternately toward and away from Earth as it circles the companion. The resulting back-and-forth shifts in the spectral features of the primary star betray the binary system, even if the companion star is invisible. This is what Plaskett saw in the spectrum of Rigel A. Because he could not see any spectral features from the companion star, he assumed the companion was too faint to be captured by his spectrograph.

Despite his painstaking observations, however, it appears that Plaskett was wrong. Decades later, improved techniques still have not revealed the spectral lines of Rigel A's putative companion. Astronomers now suspect that the observed variations in radial velocity are caused by pulsations of the outer atmosphere of Rigel A.

Meanwhile, the visible companion — Rigel B — played the lead role in a subplot that unfolded rather

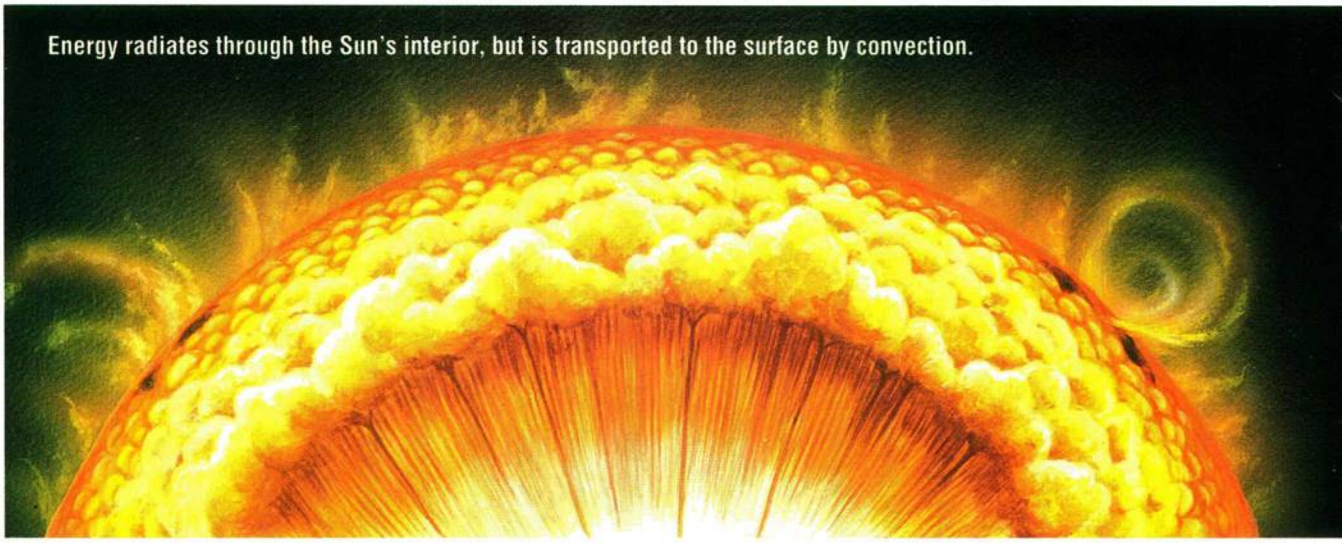


Rigel B

Mass (Sun = 1)	2.5
Diameter (miles)	1.7 million
Diameter (Sun = 1)	2
Apparent Magnitude	6.8
Absolute Magnitude	−0.4
Luminosity (Sun = 1)	100
Spectral Type	B9 V
Surface Temperature	10,100 K
Color	Blue-white

Rigel C

Mass (Sun = 1)	1.9
Diameter (miles)	1.3 million
Diameter (Sun = 1)	1.5
Luminosity (Sun = 1)	50
Spectral Type	B9 V
Surface Temperature	10,100 K
Color	Blue-white


Energy radiates through the Sun's interior, but is transported to the surface by convection.

differently. The story picks up in 1937, when spectra of Rigel B were taken at Mount Wilson Observatory. These new observations showed much greater detail than any previous observations and clearly revealed two sets of spectral lines. To everyone's surprise, instead of Rigel A, Rigel B turned out to be a spectroscopic binary! Both stars are blue main-sequence stars and they orbit one another once every ten days. There was no question about these results, as there had been with Plaskett's conclusion regarding the primary star, because both sets of lines had been captured by the spectroscope.

Even that wasn't the end of the mystery of Rigel's multiplicity, however. Over the years many observers, including such famous double-star observers as S. W. Burnham and R. G. Aitken, reported seeing Rigel B as a double star on certain occasions. The observed separation of the two stars was very small — less than 0.2 arcsecond. It doesn't appear that these observations could be of the spectroscopic companion, however. The orbital elements calculated in 1947 for the spectroscopic pair showed that these stars never get even as much as 0.1 arcsecond apart. Other observations made with large telescopes on nights with excellent observing conditions also indicate that Rigel B is not a visual double. Like Plaskett, the observers of the visual companion to Rigel B seem to have been mistaken. As Roscoe Sanford, the astronomer who calculated the orbit of Rigel B's spectroscopic companion, diplomatically put it in 1942, "the double star and spectroscopic observations of Rigel's companion are still to be reconciled."

Enveloped in Gas and Dust

In addition to its immediate family, Rigel's interstellar neighborhood also contains a cloud of dust, known as IC 2118. Immense clouds like this one are the progenitors of new stars, which form as the clouds contract and fragment under the influence of gravity. Most of the Galaxy's dust and gas resides in the spiral arms of the Milky Way. Because so many young stars congregate in this area, we see a vast number of the massive, fast-burning blue stars when we gaze toward Orion.

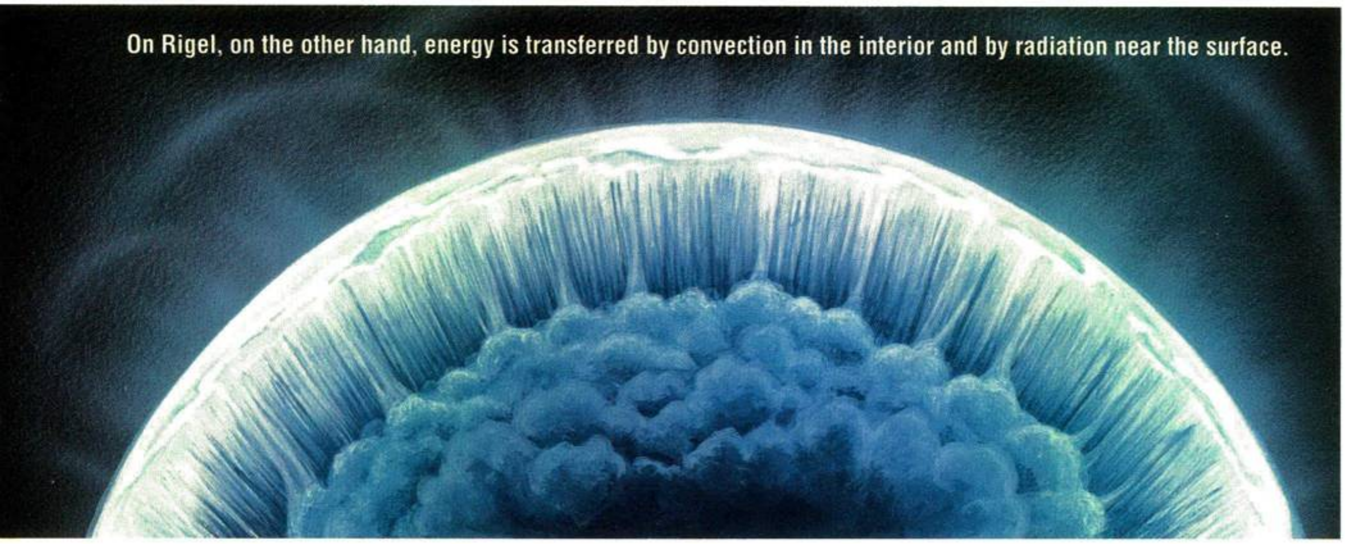
Rigel is so luminous that it illuminates the dust in IC 2118 even though the nebula lies 2.5° away in the constellation Eridanus. Observers on Earth see the cloud as a dim reflection nebula. Edwin Hubble calculated the cloud to be some 20 light-years across. He wrote that "this seems an enormous distance over which to assume stellar radiation to be effective in illuminating nebulosity." His calculations indicated, however, that Rigel's situation was not unlike that of the nebulosity surrounding the Pleiades: We see blue starlight scattered in preference to red. This is the same process that makes Earth's daytime sky appear blue.

Just as there are many Pleiads, Rigel is not alone in supervising its stellar backyard. In the mid-1960s, Canadian astronomers Sidney van den Bergh and Rene Racine studied many such cases of stars in and near reflection nebulae. They grouped Rigel and seven other stars into what is known as a "T association," named after the star T Tauri, which belongs to the first such grouping that was identified. Rigel's association is called Taurus-Orion R1 and encompasses a far greater volume of space than even the cloud Hubble observed. It's easy to imagine that hundreds, and perhaps thousands, of additional stars belong to this association, but that they are too faint to observe from Earth.

Our view of Rigel has thus been expanded to include three stars and a colossal sphere of gas: a close double, Rigel B and Rigel C, that would just about fit on opposite sides of our solar system; the bright blue supergiant itself, a hundred times farther away than the distance between B and C, or about 23 light-days; and a reflection nebula more than 20 light-years across, with the whole Rigel system suspended just beyond the tenuous outer reaches of this vast bubble.

But even this is not the whole picture. Rigel A also has a considerable shell of gas around it, which has been the subject of study for several decades. In 1986 Daniel Hayes concluded that it is likely "Rigel undergoes periodic disturbances marked by an outflow (and possible inflow) of material." In other words, the stellar material in the outermost layers of Rigel is being "puffed" outward now and then. Some of this matter later falls inward again, back toward the surface of the star.

Hayes based his conclusion on ten nights of observing the polarization of the starlight from Rigel A. Polarization is the vibration of a photon at right angles to its direction of travel. As the photon moves forward at the speed of light, it can vibrate up and down, left



On Rigel, on the other hand, energy is transferred by convection in the interior and by radiation near the surface.

and right, or at any other angle. Ordinarily, a beam of light consists of a mix of all angles. If one particular angle or range of angles predominates, astronomers say the light is polarized. Because Rigel is so bright, its light can be scrutinized in great detail, and the degree to which its light is polarized can be accurately determined.

Hayes' observations confirmed that Rigel's starlight was indeed polarized. In itself, this is hardly unusual. Many stars, particularly those with strong magnetic fields at their surfaces, radiate polarized light. What was more surprising was that the polarization of Rigel's light varied from night to night. A detailed analysis of the observations failed to turn up any pattern to this variability. Furthermore, Hayes used the polarization data to calculate that strong magnetic fields are probably not responsible for the "puffs" in Rigel's circumstellar envelope. Thus Rigel A is different from most of the other stars whose light is polarized. Instead, Hayes suggested that pulsations on Rigel's surface might be the cause of the "puffs."

Most stars seem to lose mass via "stellar winds," but these "puffs" from Rigel A are rather peculiar. Estimates vary as to how much mass is lost this way, but it seems reasonable that Rigel A could lose about 1 percent of its mass in a million years. The star puffs off a shell of gas about 100 million kilometers above its outer atmosphere. Expanding at almost 200 kilometers per second, the shell of gas would reach Jupiter's orbit in a month if Rigel A were located at the center of our solar system.

How are these puffs ejected? Are they connected to asymmetric pulsations of the star's surface? Why do they occur irregularly, and what implications does this have for our understanding of the inner workings of stars in general? Why does some of the material fall back to the surface, unable to escape Rigel's gravity? Astronomers still don't have satisfactory answers to such questions.

An Explosive Future?

For astronomers, the topic of mass loss from blue supergiants similar to Rigel took on a new urgency when Supernova 1987A burst forth in the Large Magellanic Cloud four years ago. Astronomers soon determined that the supernova's progenitor star, Sanduleak –69°202, had been just such a star. The conventional wisdom had always been that red supergiants, like Betelgeuse, were the most likely candidates to become supernovae.

Challenged to explain how a blue supergiant had met this catastrophic fate, theorists adjusted their computer models. Much to their surprise, the models predicted that a blue supergiant in an advanced evolutionary stage could indeed become a supernova — once the surface had ejected a great deal of mass. Although the shell of gas surrounding Rigel A probably does not yet contain enough mass to make the star an immediate supernova candidate, this could well be the kind of behavior that Sanduleak –69°202 exhibited in the recent astronomical past.

Of all the millions of stars like Rigel, sprinkled around the spiral arms of the Milky Way and each one bright enough to be visible across spectacularly large distances, we can see but a few. The rest are lost to us behind the dust lanes in the plane of the Galaxy. So for a small fraction of the Galaxy's diameter, the blue supergiants each reign over their own dominion, yet they are but princes on a cosmic continent.

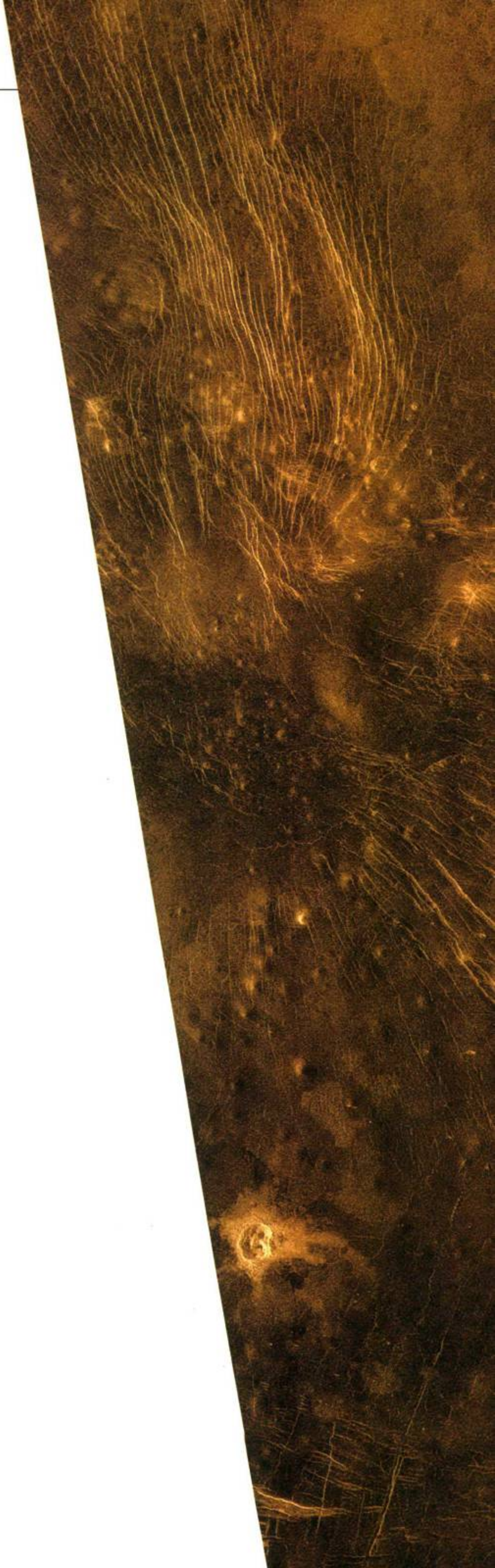
There's more here than just the raw material for a fictional galactic adventure story. The next time you gaze at Orion, imagine yourself looking over the shoulders of men like Struve, Aitken, and Plaskett, the early pioneers who tried to plumb Rigel's secrets with varying degrees of success. Peering with you are the current generation of researchers, like Hayes, who are seeking to unravel thin threads of evidence about the detailed physical structure of Rigel, its atmosphere, and its circumstellar shell. And, off to one side, are the astronomers of the apocalypse, theorizing about supernovae and the cataclysmic things that go bump in the night. Think of that the next time you spy Rigel and its cousins down the two-thousand-light-year-long tunnel of the Orion Arm, blazing away in all their short-lived celestial glory. □

Peter Jedicke is an enthusiastic amateur astronomer who teaches math and physics at Fanshaw College in London, Ontario. David H. Levy is an author and comet hunter, with six comet discoveries currently to his credit.

UPDATE on MAGELLAN

Exciting new features are emerging as *Magellan* maps its way around Venus.

by Robert Burnham



"To understand Venus, we are calling on everything we know about Earth's geology," marvels the Jet Propulsion Laboratory's Stephen Saunders, chief scientist for *Magellan*. "But at some point, we'll turn that around and Venus will start teaching us about Earth." *Magellan's* latest findings include several features of interest, including strange horseshoe-shaped deposits which have no known counterpart elsewhere in the solar system.

The northern continent of Ishtar Terra contains a large plateau called Lakshmi Planum. This plateau is rimmed on its southern edge by the Danu Montes mountain belt, which rises about 1,500 feet above Lakshmi before dropping 9,000 feet to the plains south of Ishtar. *Magellan's* new images show that the Danu Montes rim is not complete, and where the rim is missing, lava from Lakshmi Planum has spilled over the edge (see image on page 46).

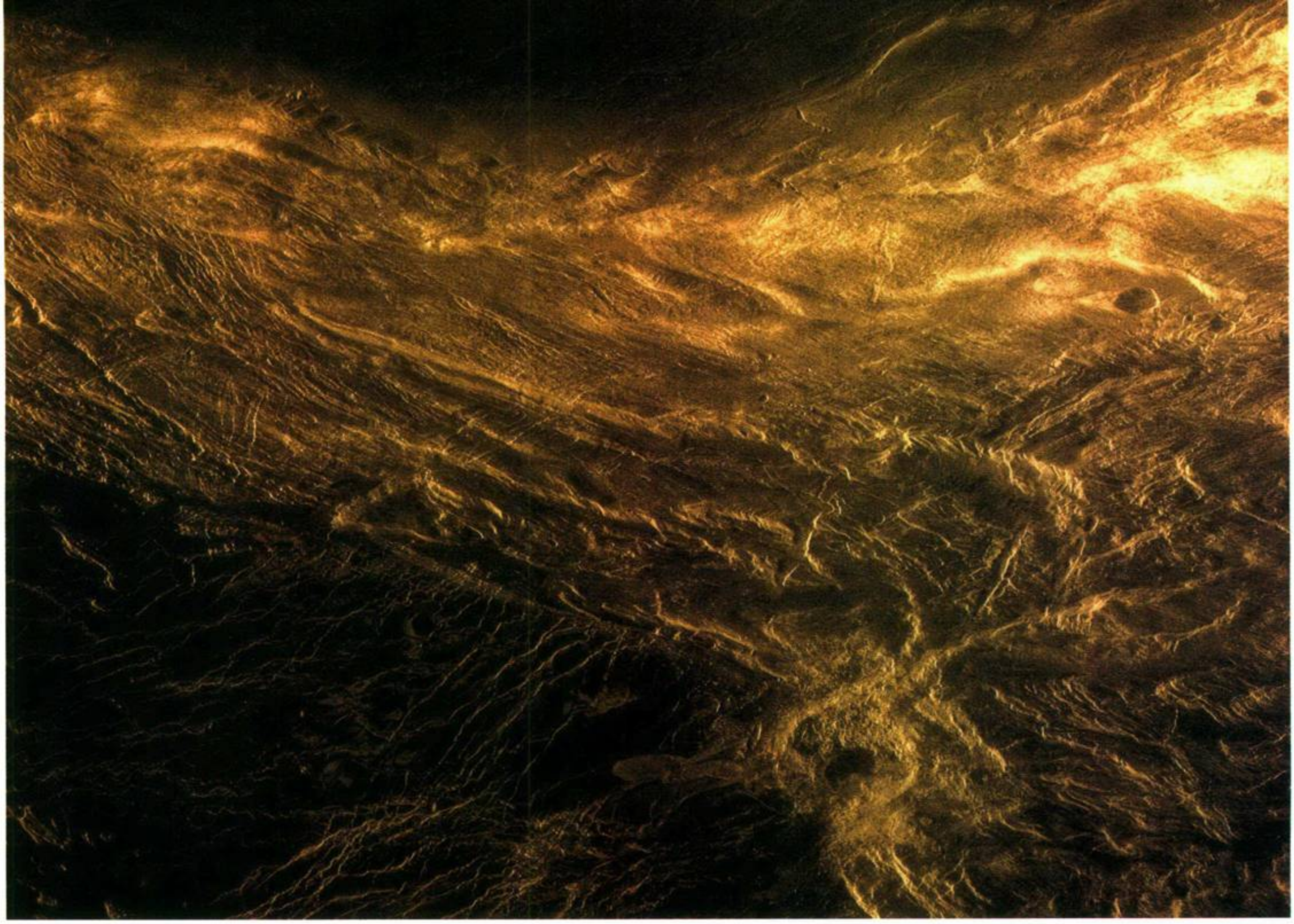
"In its composition, the crust of Venus is probably like the sea floor of Earth," remarks Sean Solomon of MIT. "But the great heat at the planet's surface [740 kelvins, or about 900° Fahrenheit] has softened the crust so that it behaves more like the relatively weak rocks of Earth's continents." Gordon Pettingill, also of MIT, adds, "These rocks are halfway to their melting points."

"In one place," says Solomon, "we mapped a lava channel that flowed across a plain until it met a ridge. The channel then detoured around the end of the ridge and eventually dispersed into a lava delta.

"But the tectonic forces that made the ridge may have kept on working after the channel formed. *Magellan's* altimeter tells us that today the place where the channel detoured is a high spot; the channel now runs downhill in both directions away from it."

Solomon points out that lava streams eroded channels in basalt plains by pouring out at high rates and temperatures. He says, "The lava just burned a fiery channel across the basalt," producing a feature like the Moon's sinuous rilles. Planetary scientist James Head III of Brown University, notes that "On

FAULTS AND VOLCANIC DOMES mingle on the plains near Alpha Regio. The dome field at left center lies amidst radar-bright faults and troughs, some of which the domes overlie. At lower left, a crater shaped like a kidney bean has a floor with multiple depressions, thought to be caused when the meteorite broke up just before striking the surface.



RADAR-BRIGHT, the Danu Montes mountain belt rims Lakshmi Planum (the dark region above) and spills southward in a tangle of folds and faults. Softened halfway to their melting points in the 900° F heat, Venus' surface rocks deform more easily than their terrestrial counterparts.

Venus, lava flows tend to be thinner and to have more gentle slopes."

Not all Venusian lava is runny, however. A small group of volcanic domes has round shapes, steep slopes, and complex, fractured surfaces. Says Saunders, "These are about 15 miles in diameter and half a mile tall, and probably contain a stiff, rather silicic, kind of lava that's unlike the more fluid basalt flows we see elsewhere."

The strange horseshoe features remain puzzling: "We've been looking at these things for a week now," says Ray Arvidson of Washington University. "And we think they're unique in the solar system." Horseshoe-shaped deposits ring a few 15-mile-diameter craters, and measure about 600 miles east to west and half that north to south. Arvidson thinks they may result from shock waves from the incoming meteorite. But, he remarks, "How much occurs at impact and how much subsequently, we can't yet say."

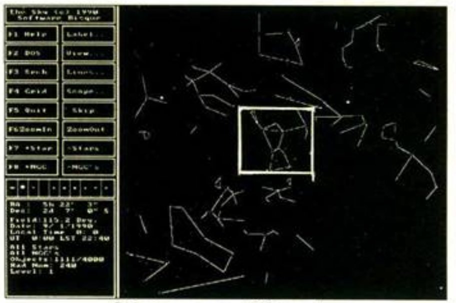
He adds, "We hope, however, that they will prove to be recent features, because this may tell us how fast Venus' surface changes. We think that volcanism renewed the surface largely or completely within the last 500 million years. We're now examining images very closely to see if we can detect interrelationships between the horseshoe deposits and lava flows."

Magellan's images also show that Venus has no craters smaller than about 4 miles in diameter. This is because the atmosphere is 90 times denser than Earth's and stops all incoming objects that would make smaller craters. More interestingly, craters in the 4- to 6-mile diameter range have floors with multiple depressions. This suggests they were made by meteorites that fragmented (due to atmospheric resistance) into tightly clustered groups of objects moving on parallel paths.

One *Magellan* experiment uses the large radar antenna to "listen" to the radio emissivity of surface rocks in hopes of studying mineral composition. No general conclusions have emerged, but, says Pettingill, "we have found some regions that are suggestive."

Maxwell Montes, for example, "poses a big problem in interpretation." Parts have electrical properties that indicate the surface contains conductive "flakes" of some unknown mineral, most likely iron sulfides, iron oxides, or magnetite. Iron sulfides ("fool's gold") fit the observations best, but studies have shown that they would be quickly destroyed by the corrosive Venusian atmosphere. Iron oxides (such as hematite) and magnetite are also possible, but the presence of either is not easy to account for.

Partway through *Magellan's* mapping mission, "Earth's twin" is appearing less and less Earthlike with each mapping swath. *What will our final picture of this* amazing world next door look like? Who knows — just stay tuned! □



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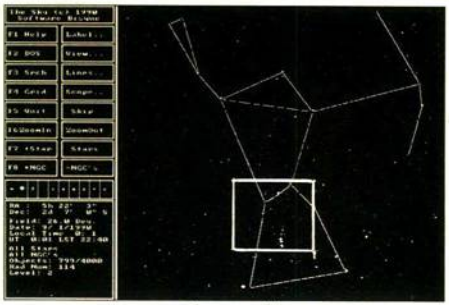

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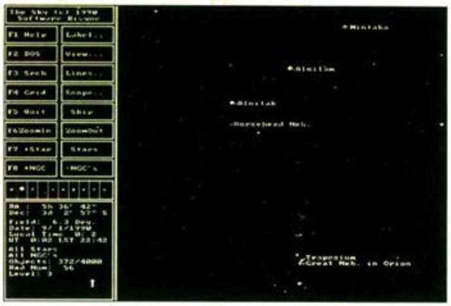

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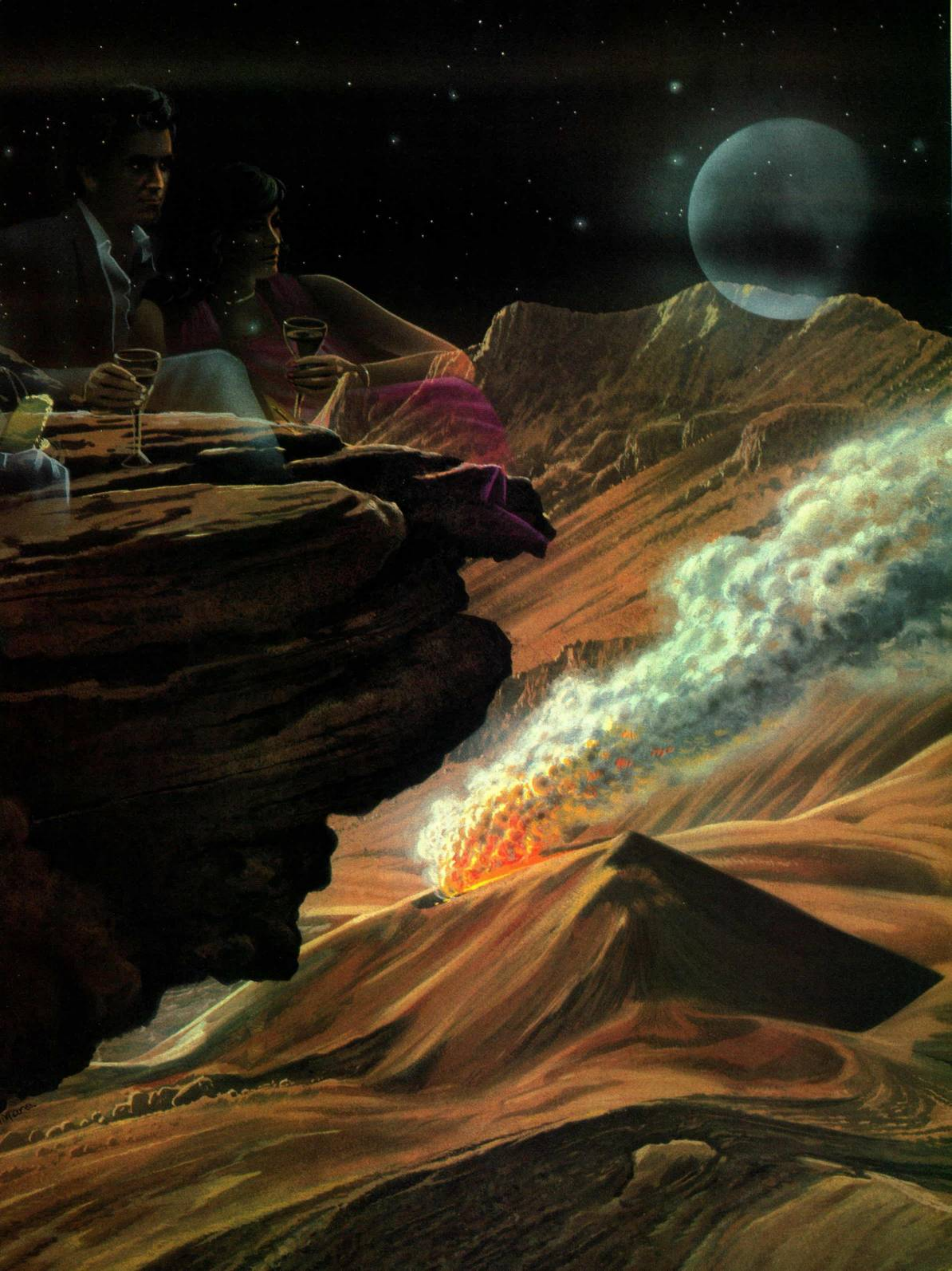


WHAT IF?

The Earth Without the Moon

The Moon is more than a pretty sight in the sky, a participant in eclipses, and a big influence on Earth's tides — without the Moon life on Earth may never have flourished.

by Neil Comins

The Moon is a permanent fixture both in our sky and in our culture. Whether it is a slim crescent or a beaming disk, the Moon adds romance to the night. It's both a free source of light for nighttime activities and a convenient stepping stone for human exploration of space. It causes tides and changes phases, both in predictable and reliable ways. The Moon's presence is so ubiquitous that it's almost impossible to imagine living without it. But what would life be like without the Moon? Would it be any different?

Let's imagine the solar system existing at the same place in our galaxy and at the same time in the history of the universe. The Earth in this new solar system has all the same characteristics as our present Earth except for one: the Moon does not exist. What effect would this one change have on Earth and its inhabitants?

A World of "What Ifs?"

Why consider the Earth without the Moon? Such a change might have enormous ramifications for the condition of Earth and perhaps even the existence of life. For example, during the last twenty years astronomers have found that the material from which the solar system formed could easily have arrayed itself differently. The theory of chaos developed during the past two decades has shown that even small changes in initial conditions can lead to enormous changes in the end product.

In the case of Earth, imagine in our scenario just one of the billions of space rocks that coalesced to form Earth heading in a slightly different direction than it did in reality. The resulting distribution of material from which Earth formed would have been so different that Earth's chemical composition, energy, and angular momentum would have been completely different. Earth's axis might have had a markedly different tilt,

An Earth without a Moon could be very different — lifeless, for starters.

leading to a different cycle of seasons. The speed of rotation around Earth's axis could have been a hundred times slower or ten times faster. Earth might have had a different chemical composition. Life may have arisen differently, may not have arisen, or might have evolved completely differently. World building serves to show how thoroughly interconnected objects and processes are in the universe, and how precarious and vulnerable Earth is to seemingly small astronomical or human-made changes.

To be sure, many hypothetical changes we impose upon our new solar system may appear small. And certainly not having a Moon is a big deal. But the forces on the early solar system necessary to create Earth without a Moon could well have been tiny, snowballing as time went on. If one speck of primordial dust had traveled a little faster than it actually did, then the mechanism that formed the Moon might have failed to materialize.

World building is also the boundary between science and science fiction. Our proposed changes are in the regime of hard science, as are most of the resulting astronomical and geological implications. The resulting world, however — one without the Moon — does not exist and in this sense marks a departure from pure science.

Earth without the Moon

Obviously, without the Moon there would be no eclipses. The Moon is a key player in such events, blocking the Sun's light in a solar eclipse, or moving into Earth's shadow in a lunar eclipse. Also, without a Moon there would be no moonlight, which is to say that all clear nights would be uniformly dark except for the effects of city lights: a blessing for astronomers who don't appreciate the Moon washing out the light from dim stars, but less enjoyable for lovers and poets.

Ocean tides are largely caused by the Moon, and so they would decrease, but not disappear. Why would tides remain? The Moon causes only about two-thirds of our tidal effect. The Sun has half as much tidal effect on us as the Moon, while the planets, especially Jupiter, cause a small fraction more. The daily range between consecutive high and low tides is determined by the positions of the Sun and Moon relative to the Earth. (We'll ignore the tiny effect of the planets.) When the Sun and Moon are in a straight line as seen from the Earth, their gravitational forces combine to cause the highest daily range of tides, the spring tides. When they are at right angles as seen from the Earth, their forces oppose each other and they create the lowest range of tides, the neap tides.

If the tides were due only to the Sun, they would have a smaller range from high to low each day since the tidal pull of the Sun is only half that of the Moon. And, since the distance from Earth to the Sun varies by only 3 percent throughout the year, the difference between neap tide and spring tide would vary by only 9 percent, unlike today, when the Moon, whose distance from the Earth varies monthly by 10 percent, causes the range to vary by over 30 percent.

The time between consecutive high tides today is the time it takes the Moon to move from its highest point in the sky to the point above the place on exactly the opposite side of Earth. You can understand this by noting that the tides are created by the difference between the gravitational force felt by the oceans nearest the Moon, by the solid parts of Earth, and by the oceans farthest from the Moon. The oceans farthest from the Moon are pulled least. The solid Earth between them and the Moon is pulled away from these oceans, creating a high tide on the opposite side of Earth from the Moon. This tide has exactly the same height as the high tide directly below the Moon, because the oceans nearest the Moon are pulled away from the same solid Earth.

The time between consecutive high tides is now about twelve hours and twenty-five minutes. It's slightly longer than half a day because the Moon's revolution around Earth is in the same direction as Earth's rotation on its axis. Earth needs an extra twenty-five minutes of rotation to out-race the Moon and get into position. Without the Moon, the length of a cycle from high to low and back to high tide would be twelve hours and four minutes or about half a solar day. This new cycle would be determined by Earth's rotation on its axis and our revolution around the Sun. The extra four minutes beyond half a day is due to Earth's motion around the Sun.

What effect would the decrease in tidal activity have had on present-day life? As an example, the intertidal zone of the ocean — the region exposed on the shoreline at low tide and covered at high tide — is a rich feeding ground for migratory birds. If the tide range were 70 percent smaller, as it would be without the Moon, the exposed surface area would be

significantly smaller and the number of bird species able to feed, or the total number of birds of any single species able to get a share of the food there, would be much smaller. In all likelihood, both the number and variety of sea-feeding birds would be less. Similarly, the number and diversity of tidal sea creatures, such as barnacles and snails, would be lower, while creatures thriving on more stable shallows would prosper. Generally, the number and variety of ecological niches available for habitation on Earth would be smaller.

Is it Bedtime Already?

An even more striking result of the Moon's presence is the fact that the friction caused by tidal water rubbing against the shore is today slowing Earth's rotation by about two milliseconds per century. Assuming this effect has been a constant for a billion years, the length of the day would have been less than twenty-one hours back then, and even shorter farther back in geohistory. As Earth slows down, the angular momentum it loses is transferred to the Moon, which speeds up in its orbit around us. As a result it is flung farther away from Earth at a current rate of 4 centimeters per year.

The combination of the slowing Earth and the receding Moon means that eventually the rate of Earth's rotation, our day, and the period of the Moon's orbit around Earth will be exactly the same. From then on, the changing tides will be due only to the Sun and other planets. And the Moon will be locked over one place on Earth so that half the world will never see the Moon again. Fear not — this won't take place for billions of years.

Without the Moon, Earth's rotation rate would have decreased much more slowly. A shorter day would have had important effects on the evolution of life. For example, today our biological clock cycle is about twenty-five hours, slightly longer than a rotation-imposed 24-hour day. Nature readjusts these internal clocks every day to be in sync with the cycle of day and night. Research physicians have found that if the day were eighteen hours, biological clocks could not be pulled into sync with Earth's rotation. Along with all other animals, we would not function well in eighteen-hour days, sleeping when we should be hunting, storing food when we should be looking for mates, and so on.

Biological clocks help creatures make the best use of each day. Nature would have had to create different kinds of biological clocks, perhaps with completely different chemistries, to accommodate shorter days.

This raises an interesting speculation about the way things did happen. Did the gradual, multimillion-year decline of the dinosaurs before the mass extinction 65 million years ago occur because the dinosaurs had faster biological clocks that got out of sync with the slowing Earth? Did the difference between the dinosaurs' clocks and the day-night cycle become so great that they weren't able to function effectively, losing the edge to the creatures with slower, but day-night synchronized, biological clocks? Perhaps if the Moon did not slow down Earth's rotation dinosaurs would still reign supreme. If days were shorter, the speed at which plants must move in order to follow the Sun through the daytime sky would be much faster, taking more of the plants' energies and perhaps requiring different internal biological structures to hold them up and move them.

Wind patterns, which are generated in large measure by Earth's rotation, would be both different and stronger. Winds on Jupiter, which rotates once every 9 hours and 50 minutes, are so strong that they create hurricanes that last for decades and perhaps even centuries. Indeed, wind patterns extend in complete rings around the surface of that planet. Imagine how life might have evolved here if it had to face continuous, gale-force winds. Like wind-bent trees, surface life would literally be shaped by the weather. Think about how we would communicate amid such howling winds.

Lunar Psychology

There is a slew of nonphysical effects associated in popular literature with the Full Moon. These include times of childbirth, stock market activity, hospital emergency room activity, and female estrous cycles. Sociologists have studied these phenomena and found they have no lunar correlation. What sociologists do find is that when people notice that a Full Moon is up, they are apt to say to themselves, "Hmm, the Moon's full, so weird things are going to happen." And if something unusual or important does happen, they conclude there is a causal relationship between the event and the Moon. In fact, equal numbers of the same events (child births, stock market changes, and so on) occur at all other times in the cycle of lunar phases.

Correlations between visual effects of moonlight and nocturnal activities by humans (night travel and night crime, for example) and other animals (night traveling, for example) are on firmer ground. It is quite clear that at least for humans, moonlight facilitates activities, but doesn't cause them. Nocturnal animals might be less successful in some of their activities, such as hunting, foraging, or traveling, with the permanent absence of moonlight. This suggests that without a Moon different biological adaptations to enhance nighttime activities would have occurred. The lack of moonlight may well have encouraged the increased development of different mechanisms for horizontal and vertical orientation in those bird species that prefer traveling on moonlit, rather than moonless, nights.

The evolution of eyes might have tracked differently, too, with greater sensitivity to infrared radiation. This radiation, some of which we already detect as heat, is emitted at night by anything that was warmed by sunlight during the day or which has its own internal heat supply, like warm-blooded animals. Perhaps if the Moon weren't here, animals, including ourselves, would have two sets of eyes: the set we now have to see visual light, and a set that detects infrared radiation for seeing more acutely at night.

The Moon as Protector of Life

So far, all of these things are matters of degree. They are changes but they are not, pardon the expression, Earth-shattering. However, in two different ways the Moon may have played a much bigger role. First, the Moon has shielded Earth from meteoroids that would have otherwise hit us. Instead of striking Earth, they have smashed into the Moon. We can see many of the scars they created on the far side of the Moon, which always faces deep space and as a result is one of the most heavily cratered surfaces in the solar system.

There are over a dozen craters on our Moon's far side with diameters of a hundred and fifty miles or more. Consider the added catastrophic effects those impacts would have had on Earth. Meteorite impacts on Earth are widely believed to have been accompanied by profound changes in Earth's atmosphere. When big meteorites strike Earth, they force some of our atmosphere into space. The impacts also throw up hundreds of cubic miles of dirt into the air. When this occurs, as evidence shows it does from time to time, this material stays suspended for several years, preventing some sunlight from reaching Earth, and causing a global winter that could also last for years. There is growing evidence that such an impact 65 million years ago caused the extinction of the dinosaurs and half the other life on Earth. Over a hundred and twenty craters have been discovered on Earth's surface. If more meteorites had struck Earth, their cumulative effects might have changed the rate of evolution by wiping out important branches of animals

Without ocean tides, Earth would have fewer ecological niches.

or even preventing mammals from establishing dominant roles.

A second Earth-shattering issue is the formation of the Moon. Consider the implication of a newly revived theory, first proposed in the 1970s, that the Moon formed after a Mars-sized object struck Earth within a few hundred million years after the Earth formed. The impact threw part of the young Earth's mantle and crust into space. The crust is the outer layer that we live on and the mantle is the layer just below it. This theory, which claims that the bulk of the Moon coalesced from this ejected material, explains several observations about the Moon more effectively than any other theory. First, the Moon has essentially the same chemical composition as the Earth's mantle. Specifically it has few refractory, or high melting-point, materials such as iron and nickel. This makes sense if the Moon came from our mantle, since most of the refractory elements in Earth sank to the core long before the alleged collision occurred.

If the Moon had just formed simultaneously with Earth, but not from it, we would expect it to have more iron and nickel than it has. And if the Moon had formed in a distant part of the solar system and had somehow been captured by Earth, there should be subtle differences in the amounts of various isotopes of oxygen each has locked in its rocks. That is, the fractions of oxygen atoms with 6, 7, or 8 neutrons in their nuclei should be different on Earth and the Moon. This is not the case. The fraction of oxygen with these different numbers of neutrons is the same on both objects, indicating that they formed at the same place in the solar system. Also, the capture mechanism for a Moon as big as ours is difficult to envision without violating conservation laws such as those concerning energy and angular momentum.

Second, the Moon lacks volatile, or low melting-point, materials like water and carbon dioxide in its rocks. These should not have all outgassed from the Moon rocks by now. By comparison, we still observe outgassing on Mercury today. The new theory neatly explains this. The energy generated by the intruder's impact would have created temperatures on Earth far greater than any it had ever experienced before. The Moon-forming collision would have created enough extra energy to heat the rocks in Earth's mantle sufficiently to bake out much of the carbon dioxide and water trapped in them before sending them into space. Consequently, the mantle rocks splashed into orbit around Earth by the impact would have had few volatiles, and so the Moon started with an extreme deficit of frozen gases and water.

Assuming this theory is correct, what would Earth be like now if that collision hadn't occurred? Depending on the angle at which the giant meteorite struck Earth, our rate of rotation was certainly changed by it. Likewise, there would have been a change to our orbit around the Sun, which is to say, our orbit would probably be more circular. Taking the difference between the mass of the Moon, gained by Earth at the impact, and the mass of the Moon lost by Earth, Earth's mass would be approximately ten percent less had the collision not occurred.

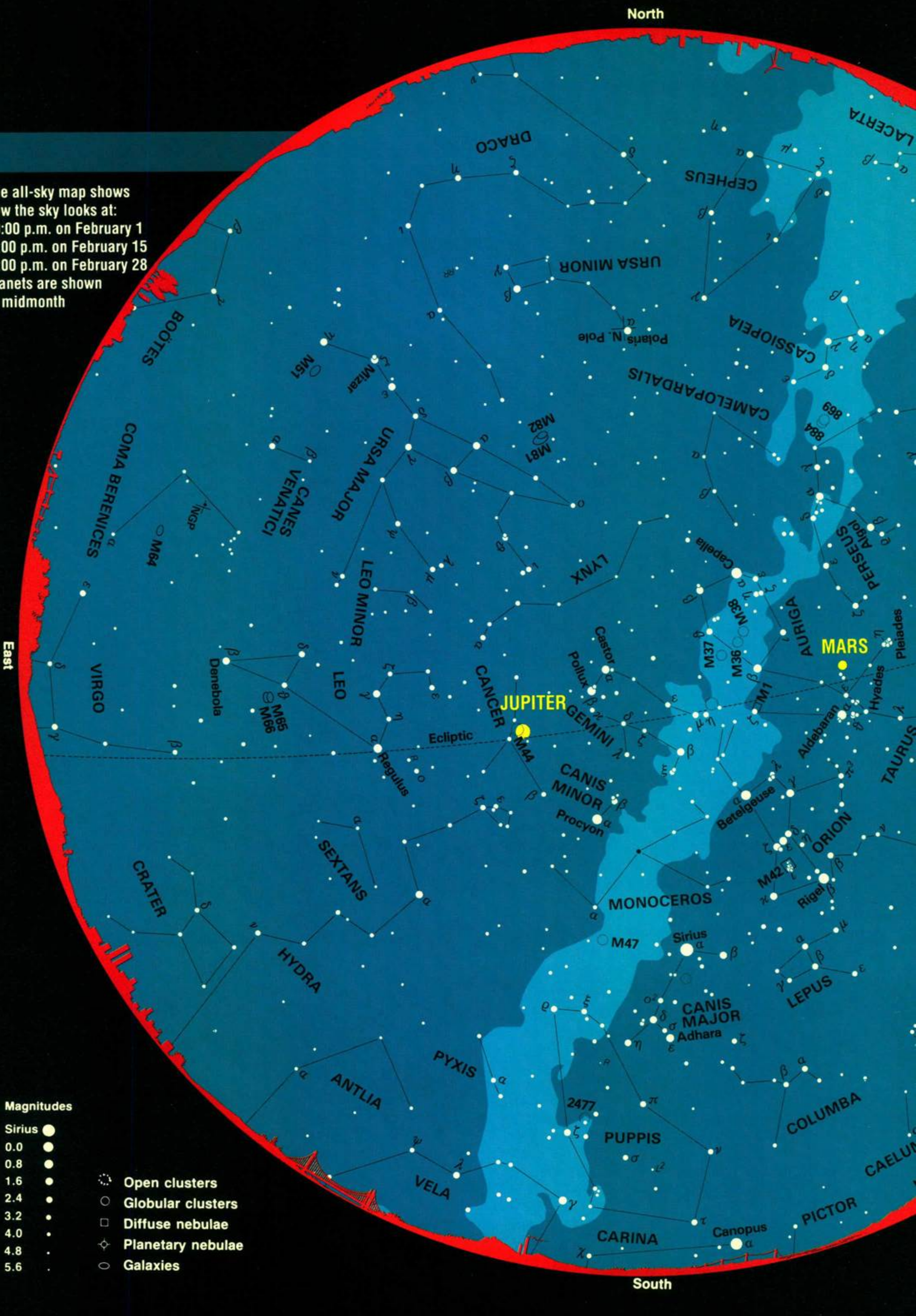
Especially intriguing is the effect of the impact on our atmosphere, which at the time was probably a combination of carbon dioxide, nitrogen, and water vapor, as is the atmosphere of Venus today. The power transferred to Earth in the collision is estimated to have been the equivalent of more than a million billion megatons of TNT. The power generated would have caused a large fraction of the atmosphere to heat violently and escape into space.

If that impact hadn't occurred, then all the gas that was liberated into space by it would still be here. Granted, some of it would have been absorbed by the oceans and taken up in carbonate rocks like limestone, but by comparison with Venus, there may have been a hundred times as much gas originally associated with Earth than is presently on Earth. At the very least, the time that Earth would have required to assimilate that gas to the point where life here could begin evolving would have been much longer. If the quantity of gas was great enough, there may not be enough water or carbonate materials on Earth to process it and leave the density of carbon dioxide low enough so that photosynthesis could convert the remainder into oxygen for animals like ourselves to breathe.

If the collision hadn't occurred and the Moon hadn't formed, there might have occurred the biggest change of all — life as we know it may never have been feasible on Earth. □

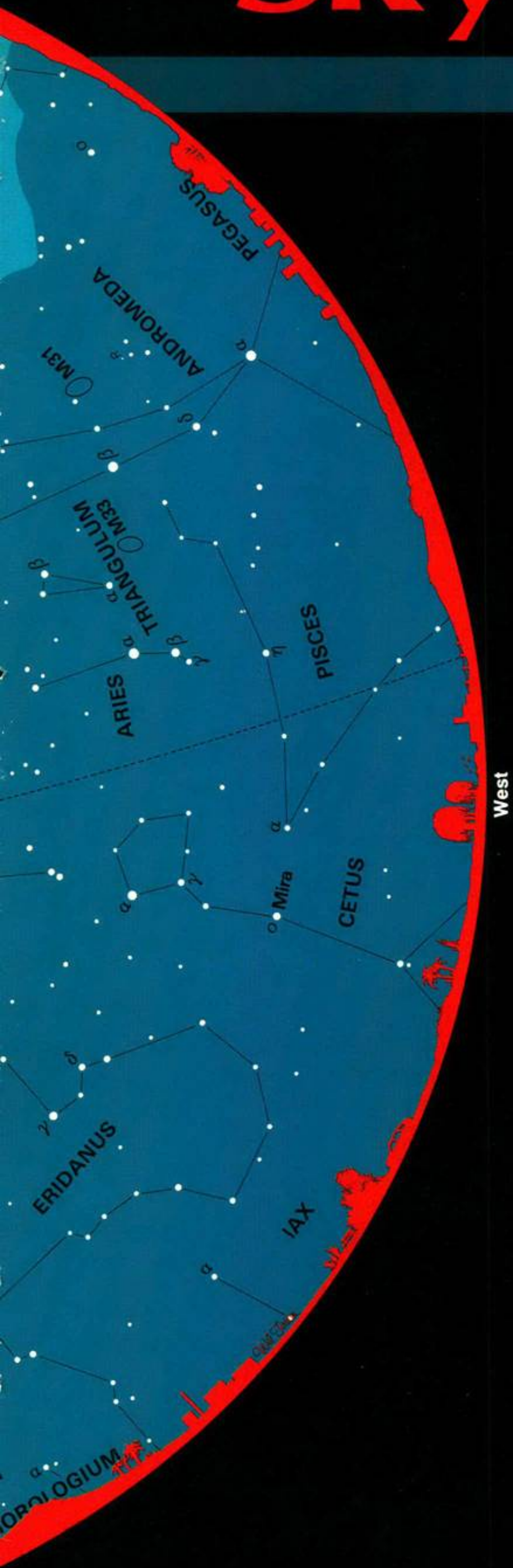
Neil Comins is an associate professor of physics at the University of Maine. His last article was "Galactic Collisions on Your Computer" in the Dec. 1988 issue.

The all-sky map shows how the sky looks at:
10:00 p.m. on February 1
9:00 p.m. on February 15
8:00 p.m. on February 28
Planets are shown at midmonth


North
South
East
DRACO
CEPHEUS
LACERTA
URSA MINOR
Polaris N. Pole
CASSIOPEIA
CAMELOPARDALIS
BOÖTES
M51
Mizar
M82
M81
869
884
COMA BERENICES
CANES VENATICI
URSA MAJOR
NGP
M64
PERSEUS
Algol
Capella
LYNX
LEO MINOR
AURIGA
M38
M37
M36
MARS
Pleiades
Castor
Pollux
VIRGO
Denebola
M65
M66
LEO
CANCER
JUPITER
M1
GEMINI
Hyades
Aldebaran
TAURUS
Ecliptic
Regulus
M44
CANIS MINOR
Procyon
Betelgeuse
ORION
M42
Rigel
SEXTANS
CRATER
MONOCEROS
M47
Sirius
HYDRA
LEPUS
CANIS MAJOR
Adhara
PYXIS
ANTLIA
COLUMBA
2477
PUPPIS
CAELUM
VELA
PICTOR
CARINA
Canopus
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

February 1991



JUPITER AND THE BEEHIVE

This month, the largest of the planets passes less than 1° from one of the more impressive binocular targets in the sky, the famed Beehive star cluster in Cancer. The pairing of the –2.6-magnitude planet and the Beehive will be an unforgettable sight in binoculars, and one that shouldn't be missed. Telescopic observers should also concentrate on Jupiter, where the series of mutual eclipses and occultations among the Galilean satellites continues this month.

THE MOON COVERS ANTARES

Much of North America can see the crescent Moon cover up the 1st-magnitude star Antares on the morning of February 8. Observers in the eastern third of the continent can see the star both disappear behind the Moon's bright limb and reappear from behind the dark limb, while those in the Midwest can see only the reappearance.

RETURN OF THE RINGED PLANET

Saturn puts in its first appearance of 1991 in February's morning sky. Look low in the southeast as morning twilight brightens for this –0.6-magnitude planet, the brightest point of light in that part of the sky. Although this would not normally be a good time to view the planet with a telescope, Saturn's recent high level of atmospheric activity should make the planet well worth observing.

Calendar of Events

5 Mercury passes 1.2° south of Saturn, 11 p a.m. EST

6 Last Quarter Moon is at 8:52 a.m. EST

8 Antares is occulted by the Moon, 6 a.m. EST
The Moon is at apogee (251,681 miles from Earth), 11 p.m. EST

12 Saturn is occulted by the Moon, 1 p.m. EST

14 New Moon is at 12:32 p.m. EST

21 First Quarter Moon is at 5:58 p.m. EST

22 The Moon passes 1.6° north of Mars, 8 a.m. EST

24 The Moon is at perigee (228,404 miles from Earth), 8 p.m. EST

26 The Moon passes 1.6° south of Jupiter, 4 a.m. EST

28 Full Moon is at 1:25 p.m. EST

Eye on the Sky by *Deborah Byrd*

JUPITER DAZZLING NEAR THE BEEHIVE CLUSTER

Early this month, after the Sun sinks below the western horizon, turn your gaze eastward and look low in the sky. There, shining creamy white against the gathering twilight, is the planet Jupiter.

Jupiter is prominent in February's evening sky because it came to opposition at the end of January. Then the planet was directly opposite the Sun as seen from Earth, and it rose at sunset. Now Earth has moved ahead in its smaller, faster orbit around the Sun, and Jupiter rises shortly before sunset. By the time evening twilight ends, the –2.6-magnitude planet dominates winter's bright stars.

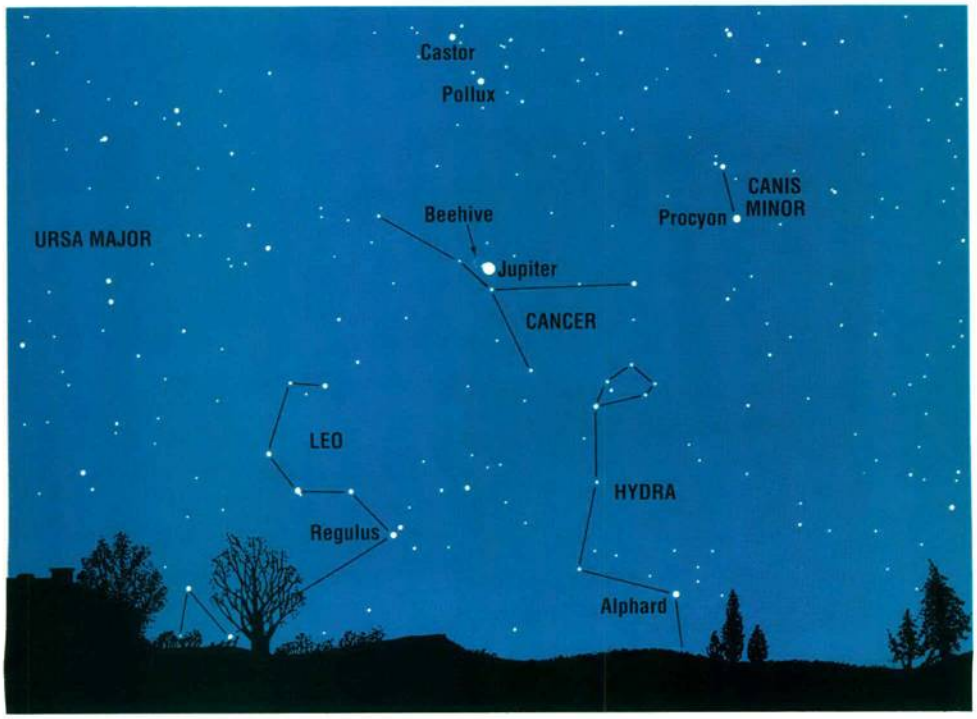
Jupiter arcs slowly across the sky through the night, setting shortly before dawn. It does so in the company of the zodiacal constellation, Cancer the Crab. Although Cancer is surrounded by a number of bright stars, it has no conspicuous stars of its own.

But observers with binoculars know that a beautiful star cluster lies at the heart of the Crab. This cluster is known as the Beehive, or Praesepe. Jupiter moves westward along the Beehive's southern edge during February. If you aim your binoculars at Jupiter, you'll find the cluster in the same field of view. The two are closest on the evening of February 7.

The proximity of the cluster to Jupiter is just an illusion, however. The Beehive — a collection of roughly 200 stars bound loosely by gravity — lies far beyond the solar system. The light we receive from the Beehive's stars left that cluster over 500 years ago, while the light we see from Jupiter took only about half an hour to reach us.

THE DANCE OF JUPITER'S MOONS

When you point your binoculars in the direction of Jupiter and the Beehive, be sure to look for four starry points strung out in a line that bisects Jupiter at its equator. These are the four Galilean satellites, named for Galileo, who was the first to glimpse them through a telescope. Few objects in the heavens play a more important role in the history of astronomy as these little moons. They were visible proof to Galileo — as they are to us today — that not all objects in the universe circle around our planet Earth.



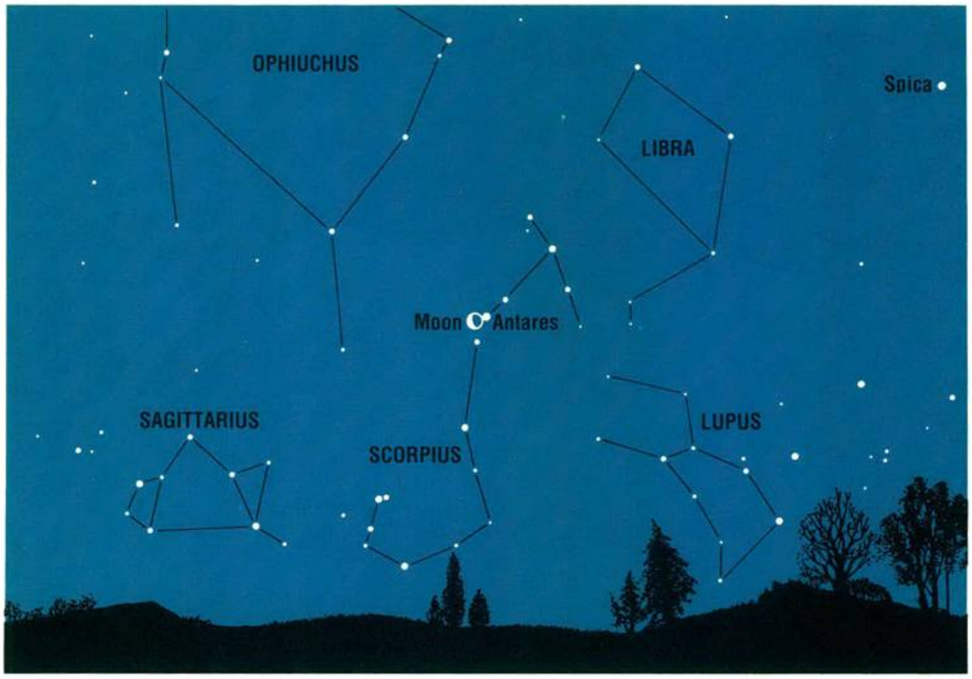
JUPITER GRAZES THE BEEHIVE in February's evening sky. The brilliant planet is closest to the bright star cluster on the 7th, when they are high in the east after nightfall.

The Galilean satellites are best seen with a telescope, but steadily held binoculars can also reveal them. If your binoculars reveal all four moons one evening, and then you look the following evening and see only three (or even two), don't be dismayed. You have just witnessed the most exciting aspect of Jupiter's moons. That is, they move. When you see four moons one night and only three the next, it is because one of the moons is hidden behind Jupiter, is passing in front of the planet, or is eclipsed by Jupiter's shadow.

THE MOON SLICES THROUGH THE SCORPION'S HEART

An exciting occultation occurs on the morning of February 8 when the Moon passes in front of the bright star Antares. Observers in most of the eastern half of the United States and Canada can see the 33-percent-lit crescent Moon cover the brightest star in Scorpius shortly before dawn.

Because the Moon's phase is waning at the time of the occultation, Antares disappears behind the bright limb of the Moon and reappears from behind the Moon's dark limb. Binoculars will help you follow the star as the Moon approaches and then covers the star. When Antares reappears it will seem to "pop out" from behind the unlit part of the Moon. See the table at right for the times of disappearance and reappearance as seen from various cities.



THE MOON SLIDES PAST ANTARES before dawn on February 8, occulting this ruddy star for observers in most of the eastern United States and eastern Canada. Use the table below to find out when the star disappears and reappears in your area.

OCCULTATION OF ANTARES

City	Disappears	Reappears
Atlanta	3:55 EST	5:12 EST
Chicago	—	3:50 CST
Dallas	—	4:13 CST
Halifax	5:41 AST	6:41 AST
Miami	3:58 EST	5:14 EST
Montreal	4:22 EST	5:29 EST
New York	4:13 EST	5:29 EST
Toronto	4:10 EST	5:23 EST
Washington	4:07 EST	5:25 EST

FEBRUARY'S PLANETS

Venus returned to view in the southwest after sunset around the beginning of 1991. The planet spends the month of February low in the evening twilight, glittering brilliantly at magnitude –3.9.

On the evening of February 15, an extremely slim crescent Moon lies 12° below and to the right of Venus. Use binoculars to sweep for it if you can't find it with your naked eye. The next evening, a fatter crescent Moon lies about 5° to the upper right of Venus. If you look carefully on these two nights, you may see the unlit portion of the Moon glowing dimly. This glow is called "earthshine." It's actually sunlight that has bounced off Earth onto the Moon.

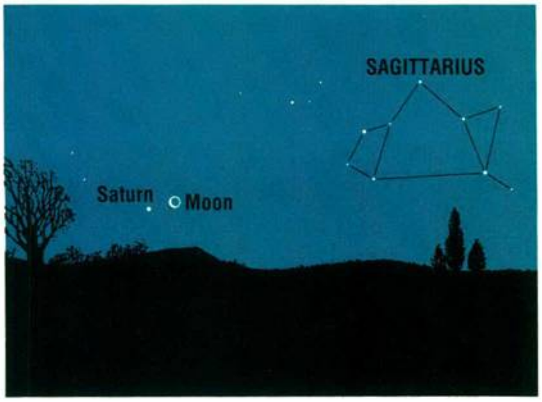
High in the south as the night begins is ruddy Mars. Although it is bright at magnitude 0.3, it is not particularly conspicuous because there are so many bright stars in that part of the sky.

Mars is once again sliding eastward against the stellar backdrop of Taurus. On the night of February 21/22, it lies 8° north of the brightest star in Taurus, Aldebaran. A gibbous Moon adds interest to the view that night, lying about 5° away from the Red Planet.

Jupiter is just a few days past opposition when February begins. It shines steadily and, at magnitude –2.6, brilliantly in the eastern sky each evening. You'll enjoy seeing Venus low in the west and Jupiter low in the east during the early evening hours this month. Also look for Jupiter on the morning of February 26, when the Moon passes less than 2° from the planet.

Elusive Mercury lies very low in the east-southeast before dawn during the first few days of February. Find an area with a clear, unobstructed horizon in that direction, and bring along your binoculars. It's too bad Mercury is difficult to see this month, because it sweeps just 1.2° south of another planet, Saturn, on February 5. The pair is slightly easier to see from the southern United States. Mercury disappears in the glare of dawn after the first week of February and spends the remainder of the month moving toward superior conjunction, which occurs in early March.

Saturn was lost in the Sun's glare throughout January, but it becomes visible again in the morning sky by the second week of February. Look low in the east-southeast about forty-five minutes before sunrise for the 0.6-magnitude planet.



SATURN RETURNS to the morning sky in February, where it appears low in the southeast half an hour before sunrise. It lies near the crescent Moon on the 12th, destined to be occulted after daybreak.

Saturn celebrates a significant event in early February. After spending the past three years among the stars of Sagittarius, it moves into the next zodiacal constellation, Capricornus.

On the morning of February 12, the Moon is poised to occult Saturn. Observers in Hawaii should have a good view of the occultation, which occurs just before dawn. Observers in the rest of North America, however, will need telescopes to see the event because it occurs after the Sun rises.

FEBRUARY'S STARRY SKY

Winter evenings bring a chill to our bones and a sharpness to the air, but they also provide a glittering array of brilliant stars. None of these stars shines as brightly as the king of planets, Jupiter, which is also in the evening sky now. But Jupiter only adds to our enjoyment of seeing so many bright stars in this one region of the heavens.

The brightest of all these stars is Sirius, in the constellation Canis Major, the Greater Dog. Sirius shines at magnitude –1.5.

You can find Sirius easily this month just by looking for the second-brightest light in the evening sky, after Jupiter. It also helps that an imaginary line drawn through the three stars in Orion's belt and extended toward the southeast points to Sirius. The star is about 20° from the belt of Orion.

Sirius is sometimes called the Dog Star. Early stargazers believed that the brilliance of this star influenced summer temperatures. Each summer, Sirius lies behind the Sun as seen from Earth. The early skywatchers thought that the double whammy of Sirius and the Sun actually caused the hot weather. Because Sirius is known as the Dog Star, a name that stems from its place in Canis Major, the hottest part of summer came to be known as the "dog days."

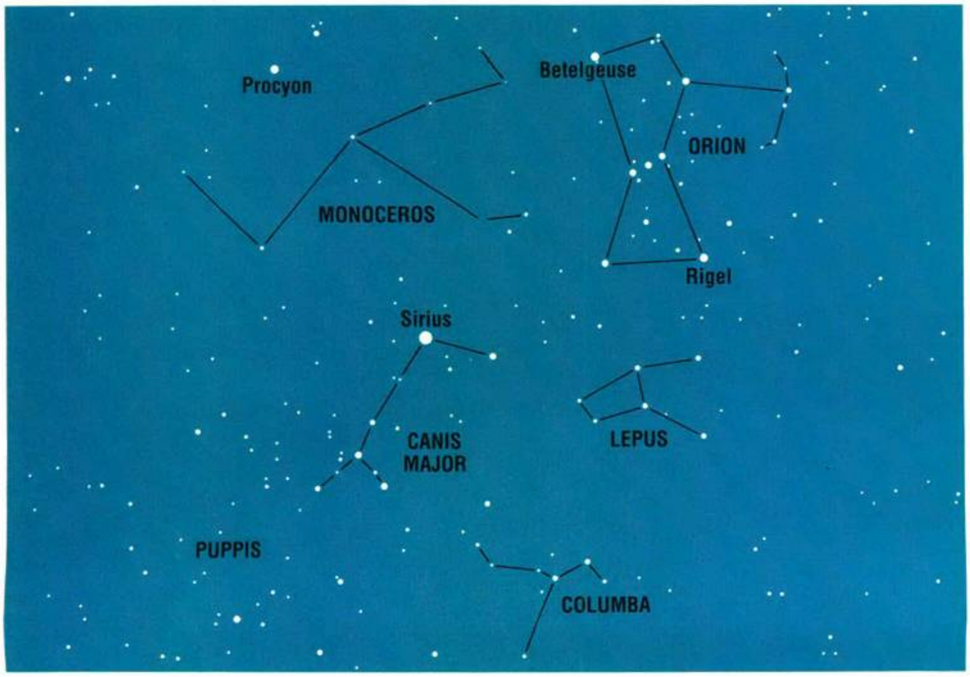
The name Sirius comes from a Greek word meaning "sparkling," and indeed Sirius does sparkle with a special intensity. It travels a low arc across the southern sky on winter nights, so when we look at it, we're often looking through a large amount of Earth's atmosphere. The brilliance of Sirius, combined with this greater-than-usual thickness of air, causes the star to twinkle fiercely.

It also causes Sirius to flash different colors. When you stand outside on a winter night, notice the flashing blues, reds, and yellows of Sirius. People are often so surprised to see Sirius' flashing colors that they report the star as a UFO.

When it's highest in the south, Sirius twinkles less. Then it shines with what's often compared to the brilliance of a diamond. The crisp air of winter and the glittering diamond-brilliance of Sirius are an unbeatable combination.

Sirius is also known for its companion star, Sirius B. This object, discovered in 1862, was the first known white dwarf. It's a highly evolved star that has collapsed to a tiny size and an extreme density. A tablespoon of the material composing Sirius B would weigh as much as a baby elephant! □

SIRIUS, THE DOG STAR, is the brightest star in the sky at magnitude –1.5. Sirius and the other stars of Canis Major can be seen faithfully chasing Orion across the winter sky due south around 9:00 p.m. local time.



Deborah Byrd is the creator, writer, and producer of "Star Date," an independently syndicated daily radio series on commercial and public radio.

Through the Eyepiece *by* *Rick Shaffer*

SPOTLIGHT ON JUPITER

Having reached opposition in late January, Jupiter moves into the evening sky as February begins. The giant planet should be the most exciting solar system object to focus your telescope on during the clear, frosty evenings of February. It is bright and high in the east, and features a large, detailed disk in the eyepiece.

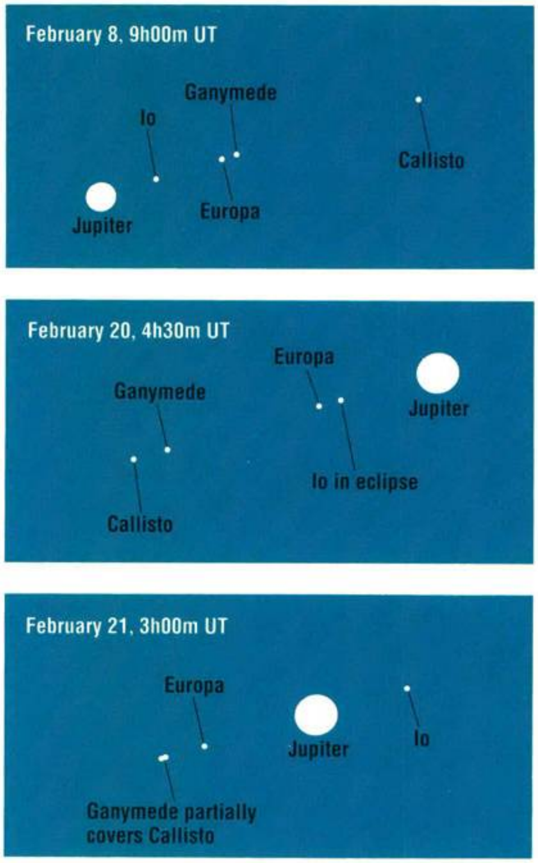
Jupiter lies along the northern part of the ecliptic, in the constellation Cancer, so when it crosses your meridian it is near the highest altitude it can get from mid-northern latitudes. The planet culminates around 11 p.m. local time on February 15, passing only 20° from the zenith for observers at 40° north latitude. The –2.6-magnitude point of light easily outshines every star in the sky.

With Jupiter high in the sky where the seeing is often good, the planet should show a wealth of interesting atmospheric detail on its huge, 45"-diameter disk. Foremost among these features are the South Equatorial Belt, which by now has regained most of its former prominence, and the Great Red Spot, which has faded noticeably in the past year.

Not all of the excitement surrounding Jupiter is in the planet's atmosphere, however. Because Earth this month lies nearly in Jupiter's equatorial plane, which is also the plane of the satellites' orbits, the pace of mutual occultations and eclipses among the Galilean satellites continues strong. (See "Watch Jupiter's Moons Play Tag" in the January 1991 issue for details on observing all the Jovian satellites' mutual events.)

Most of the mutual events this month involve the innermost two moons, Io and Europa, and these events occur in pairs. First, Europa passes in front of and partially hides, or occults, the slightly larger Io. Shortly after the occultation is over, Europa's shadow covers Io and the volcanically active satellite goes into eclipse.

On February 2, an eclipse of Io by Europa begins just 2 minutes after the preceding occultation ends. In fact, an observer that night can watch the entire occultation and eclipse in a span of less than half an hour, from 10h02m to 10h26m UT (5:02 a.m. to 5:26 a.m. EST). As the month progresses, the time between occultation and eclipse lengthens; by the morning of February 27, more than an hour elapses between the end of the occultation and the beginning of the eclipse.



JUPITER'S GALILEAN SATELLITES offer plenty of treats for telescopic observers this month, ranging from interesting alignments to mutual eclipses and occultations.

MUTUAL EVENTS OF THE GALILEAN SATELLLITES

Date	Begin Time	End Time	Event	Type of Event	Light Loss	Distance
Feb. 2	10h02m	10h12m	Europa Occults Io	Partial	29%	6
Feb. 2	10h14m	10h26m	Europa Eclipses Io	Annular	67%	6
Feb. 9	12h14m	12h23m	Europa Occults Io	Partial	36%	6
Feb. 9	12h46m	12h56m	Europa Eclipses Io	Annular	70%	6
Feb. 13	1h19m	1h28m	Europa Occults Io	Partial	39%	6
Feb. 13	2h00m	2h09m	Europa Eclipses Io	Annular	70%	6
Feb. 20	3h29m	3h37m	Europa Occults Io	Annular	40%	6
Feb. 20	4h26m	4h34m	Europa Eclipses Io	Annular	67%	6
Feb. 21	1h05m	3h27m	Ganymede Occults Callisto	Partial	12%	9
Feb. 27	5h39m	5h46m	Europa Occults Io	Partial	35%	6
Feb. 27	6h50m	6h58m	Europa Eclipses Io	Annular	65%	5

Begin Time: Universal time at beginning of event. (Subtract 5 hours to convert to EST, 6 hours for CST, 7 hours for MST, and 8 hours for PST.) **End Time:** Universal time at end of event. **Event:** The nature of the event and the satellites involved. **Type of Event:** Whether the event is partial, total, or annular. **Light Loss:** For eclipses — the percent of light lost by the eclipsed satellite at midevent; For occultations — the percent of light lost from the combined light of both satellites at midevent. **Distance:** The apparent distance of the satellite from Jupiter's center expressed in Jovian equatorial radii.

The only mutual event visible from North America this month that does not involve Io and Europa occurs on the evening of February 20. Beginning at 1h05m UT on the 21st (8:05 p.m. EST on the 20th), Ganymede passes in front of Callisto. The occultation lasts for over 2 hours, ending at 3h27m UT (10:27 p.m. EST). If you're blessed with excellent seeing that night, you should be able to resolve the disks of the two satellites during the occultation with an 8-inch or larger scope. Under less than ideal conditions, however, the two satellites will merge into one and appear indistinguishable.

MORE SATURN SURPRISES?

If this were an ordinary month, few planetary observers would give Saturn more than a cursory look. After all, for most of February Saturn barely clears the murk near the southeastern horizon before morning twilight brightens the sky.

But these are far from ordinary times. Saturn, whose classic beauty has remained nearly constant during the 32 years I've been observing it, has suddenly become a center of atmospheric chaos. It all began last September, when Alberto Montalvo found a small white spot in the planet's Equatorial Belt. The spot quickly grew in size and was dubbed the "Great White Spot."

The Spot soon developed into a streak, then into a spur on the Equatorial Belt, and then merged into a new and wider Equatorial Belt. This activity unquestionably rates as one of the great atmospheric events in the recorded history of Saturn. Observers have continued to see fresh eruptions taking place in the newly widened Equatorial Belt.

This recent spurt of activity gives all of us an incentive to get up early to observe Saturn as it returns from solar conjunction. Unfortunately, the 0.6-magnitude planet stays low in the sky and has a relatively small disk, only 15" in apparent diameter, this month. To get a decent view, you'll need to follow a few simple steps.

First, choose an observing site with an unobstructed view toward the southeastern horizon. Second, be sure your telescope has cooled to match the outside temperature well before Saturn becomes visible. With Saturn rising around 5 a.m. local time, you should have your scope set up by no later than 4 a.m. And finally, find an observing site free of obvious heat sources such as buildings, highways, and parking lots.

Another interesting Saturnian event, but one that's very difficult to observe, occurs on the morning of February 12. On that day, a 4-percent-lit crescent Moon passes between Saturn and Earth, occulting the ringed planet for observers in much of the United States. All or part of the event is visible from eastern and southern North America and from Hawaii.

The difficulty in observing this event is that for most observers it occurs in broad daylight. To see it, you'll have to find Saturn before the Sun rises and let your clock drive keep it centered until the occultation. Only in Hawaii is the event visible before the Sun rises, and even there the Moon and Saturn are bathed in strong twilight.

AN EASIER OCCULTATION

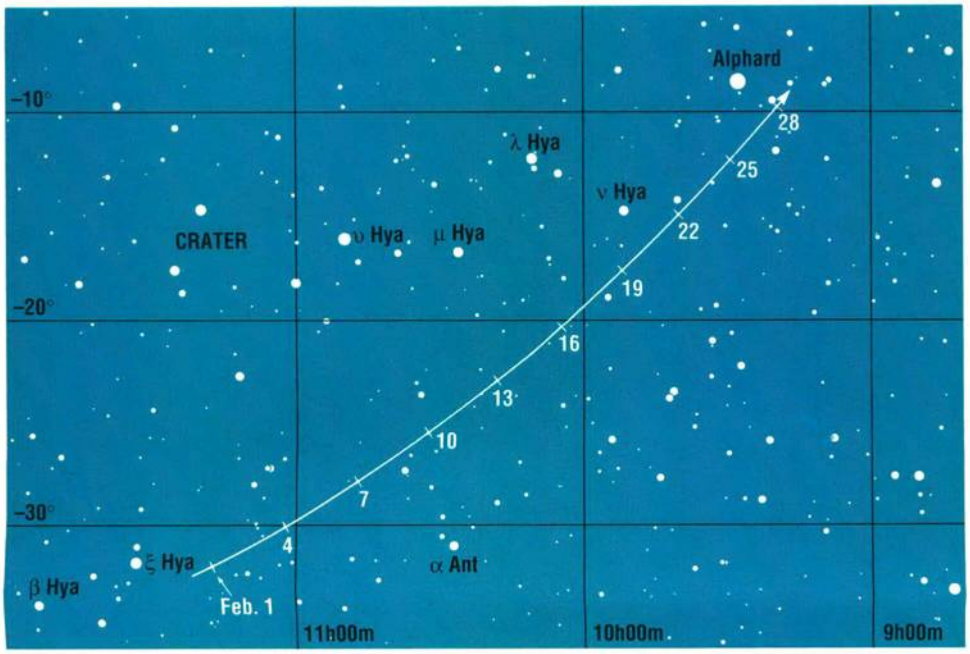
If you enjoy observing occultations, but the difficulties of doing so by day seem too daunting, you'll have a much better event to watch on the morning of February 8. That's when the waning crescent Moon passes in front of the 1st-magnitude star Antares.

Observers on the East Coast of the United States and Canada should have the best view of the event because it occurs well after the Moon and star rise but well before the Sun rises. As you go farther west, the occultation takes place with the objects closer to the horizon. In most of the midwest only the end of the occultation is visible, and in the

COORDINATES FOR COMET LEVY

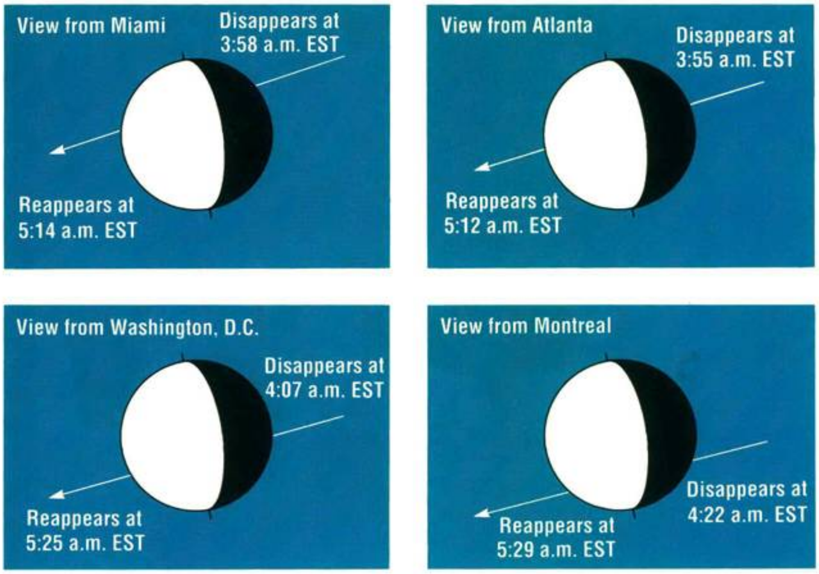
Date	R.A. (2000)	Dec.
Feb. 1	11h17.3m	–32°03'
Feb. 4	11h02.2m	–30°06'
Feb. 7	10h47.2m	–27°55'
Feb. 10	10h32.5m	–25°33'
Feb. 13	10h18.3m	–23°00'
Feb. 16	10h04.8m	–20°22'
Feb. 19	9h52.0m	–17°40'
Feb. 22	9h40.2m	–14°59'
Feb. 25	9h29.3m	–12°21'
Feb. 28	9h19.4m	–9°48'

COMET LEVY CLIMBS HIGHER into the sky and becomes easier to see as it moves north through Hydra during February. Positions are shown at 4 a.m. EST (3 a.m. CST, 2 a.m. MST, and 1 a.m. PST).



western half of the continent the occultation is over by the time the participants rise.

Occultations by a waning Moon are more difficult to observe than waxing-Moon occultations. That's because the lit portion of the waning Moon leads the way as our satellite approaches the star. Even a 33-percent-lit Moon, as we have for the Antares occultation, puts out a lot of light and makes it difficult to track the star as the lunar limb moves closer. Antares reappears on the unlit part of the Moon, an event that is more difficult to see than you might expect because it occurs without warning.


View from Miami
Disappears at 3:58 a.m. EST
Reappears at 5:14 a.m. EST
View from Atlanta
Disappears at 3:55 a.m. EST
Reappears at 5:12 a.m. EST
View from Washington, D.C.
Disappears at 4:07 a.m. EST
Reappears at 5:25 a.m. EST
View from Montreal
Disappears at 4:22 a.m. EST
Reappears at 5:29 a.m. EST

THE MOON OCCULTS ANTARES for observers in eastern North America on the morning of February 8. The Moon's path in front of the star differs significantly depending on where you observe from. South is at top to match the view in an inverting telescope.

TELESCOPIC PLANETS

Mercury remains in the morning sky during the first half of February, but it is low in the east-southeast before sunrise and difficult to see. Your best chance to see it is on the 1st, when the 86-percent-lit planet measures 5.3" across and shines at magnitude –0.3.

You won't have any trouble locating Venus, however. The brightest planet is so bright at magnitude –3.9 that it is easy to spot even when it's near the horizon. Look to the western sky about half an hour after sunset for the 11.2"-diameter, 91-percent-lit planet. Although it will be a few more months before you'll see rapid changes in Venus' telescopic appearance, it will steal the show this spring and summer.

The bright ruddy object high in the sky after sunset is none other than Mars. The high altitude is its saving grace this month — it gives you a chance to view the planet through nearly the least amount of our turbulent atmosphere as possible.

Unfortunately, this is the last month you'll be able to see the Red Planet well through your telescope. It's hard to believe that the planet's current apparition is winding down, but it's true. Mars' disk shrinks from 9.9" across to 7.8" across during February, and it is difficult to see any but the most obvious features when it is smaller than that.

To see as many details as possible when you observe Mars, try using a red filter. It will make the "green" albedo features appear very dark and prominent. And if you happen to get one of those rare windows of great seeing, run up the power as much as you can. You won't have a better opportunity for over a year.

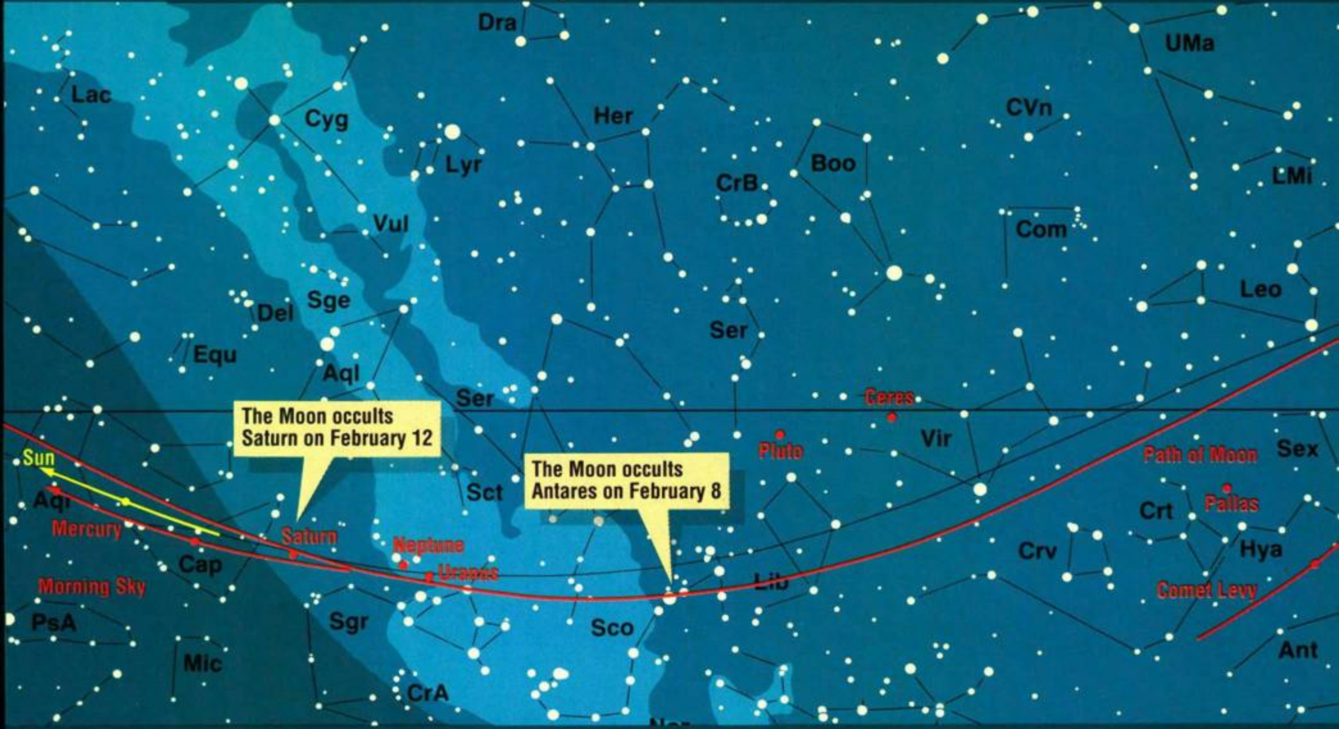
COMETS FOR THE TELESCOPE

Last year's premier comet, Comet Levy, once again becomes an easy telescopic object for observers in the Northern Hemisphere. The comet moves rapidly northward through Hydra in February, climbing higher in the sky with each passing day. It is also fairly bright, though it does fade slowly from around 8th to 9th magnitude as the month progresses.

To find Comet Levy this month, use the finder chart or table of coordinates on the opposite page. The comet should appear as a featureless blob with little or no discernible tail. □

Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He leads the data management team on the Ulysses *mission, which is on its way to Jupiter and ultimately the Sun.*

The Solar System February 1991


Dra
UMa
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Ceres
Vir
Pluto
Sun
Path of Moon
Sex
Aqr
Sct
Crt
Pallas
Mercury
Saturn
Neptune
Uranus
Cap
Crv
Hya
Morning Sky
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Comet Levy
PsA
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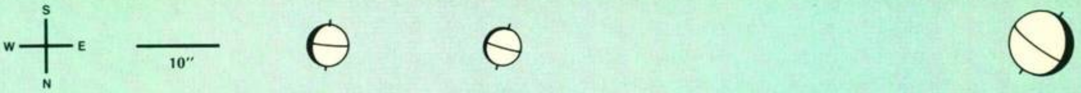
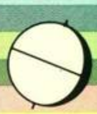
CrA

The Moon occults Saturn on February 12

The Moon occults Antares on February 8

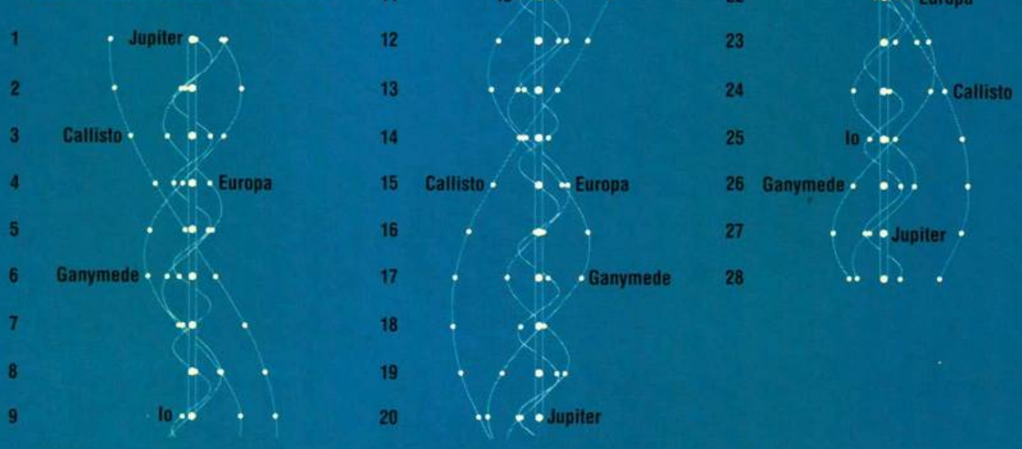


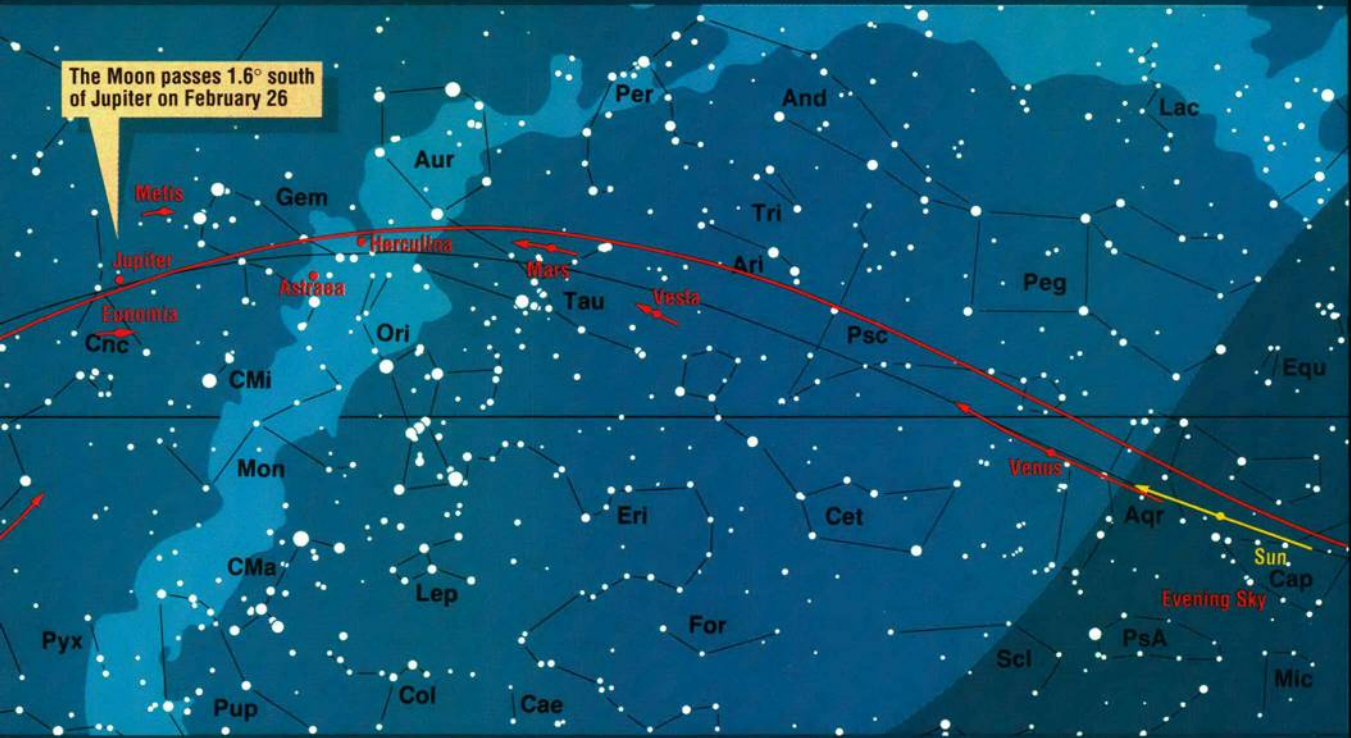


Planet	MERCURY	MERCURY	VENUS	MARS
Date	February 1	February 15	February 15	February 15
Magnitude	–0.3	–0.6	–3.9	+0.3
Angular Size	5.3″	4.9″	11.2″	8.7″
Illumination	86%	95%	91%	90%
Distance (AU) from Earth	1.269	1.371	1.485	1.076
Distance (AU) from Sun	0.466	0.450	0.725	1.605
Right Ascension (2000.0)	19h39.0m	21h10.3m	23h29.0m	4h23.0m
Declination (2000.0)	–22°26′	–18°23′	–4°44′	23°52′

Jupiter's Moons

Dots display positions of Galilean satellites at 4 UT on date shown. South is at top to match the view in a telescope.




The Moon passes 1.6° south of Jupiter on February 26

Per
And
Lac
Aur
Metis
Gem
Tri
Herculina
Jupiter
Mars
Ari
Peg
Astraea
Tau
Vesta
Eunomia
Cnc
Ori
Psc
CMi
Equ
Mon
Venus
Eri
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Mic
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Cae
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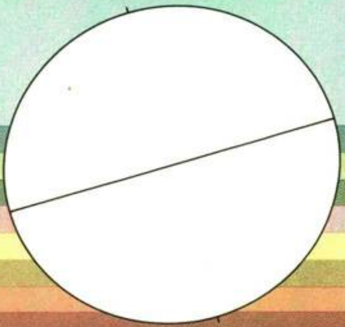
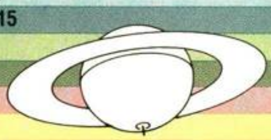
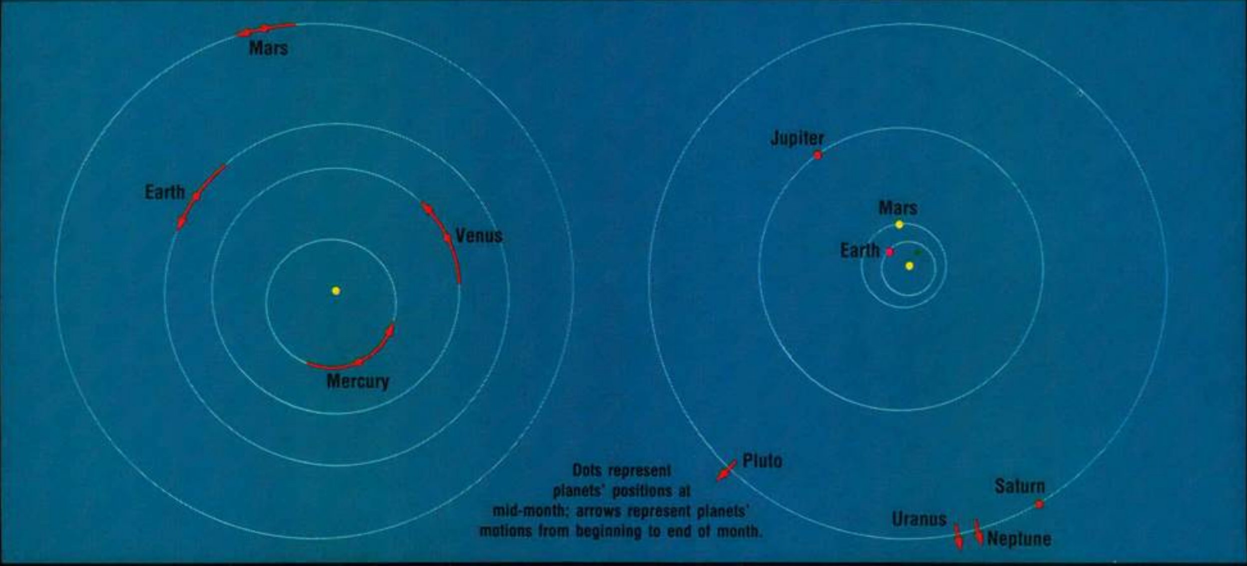




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 15	February 15	February 15	February 15
−2.6	+0.6	+5.8	+8.0	+13.7
45.2"	15.2"	3.5"	2.2"	0.1"
100%	100%	100%	100%	100%
4.355	10.873	20.157	30.950	29.562
5.297	9.985	19.453	30.201	29.668
8h36.4m	20h13.3m	18h53.9m	19h08.4m	15h28.2m
19°24'	−20°07'	−23°12'	−21°43'	−3°08'

The Planets in Their Orbits

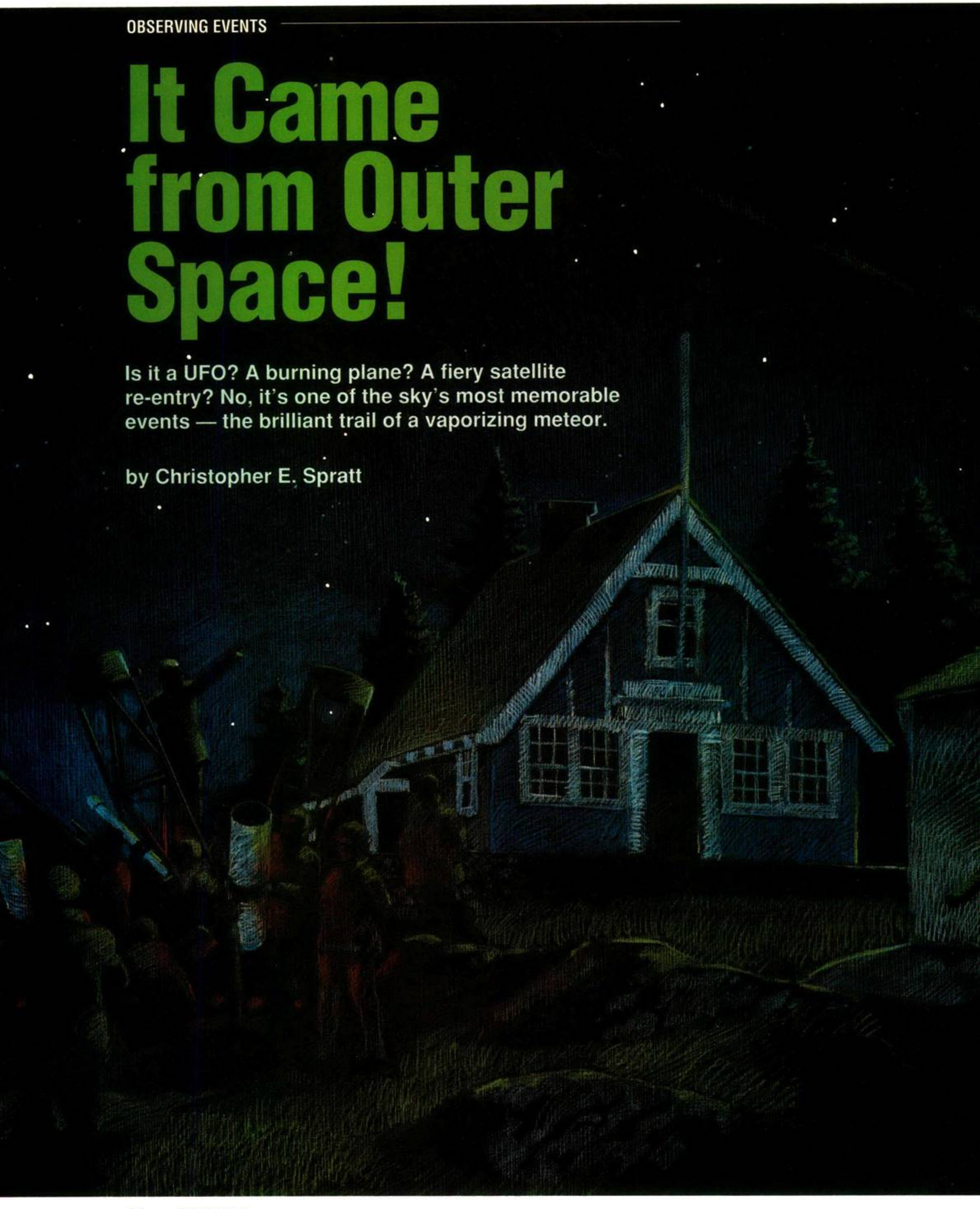

Mars
Earth
Venus
Mercury
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

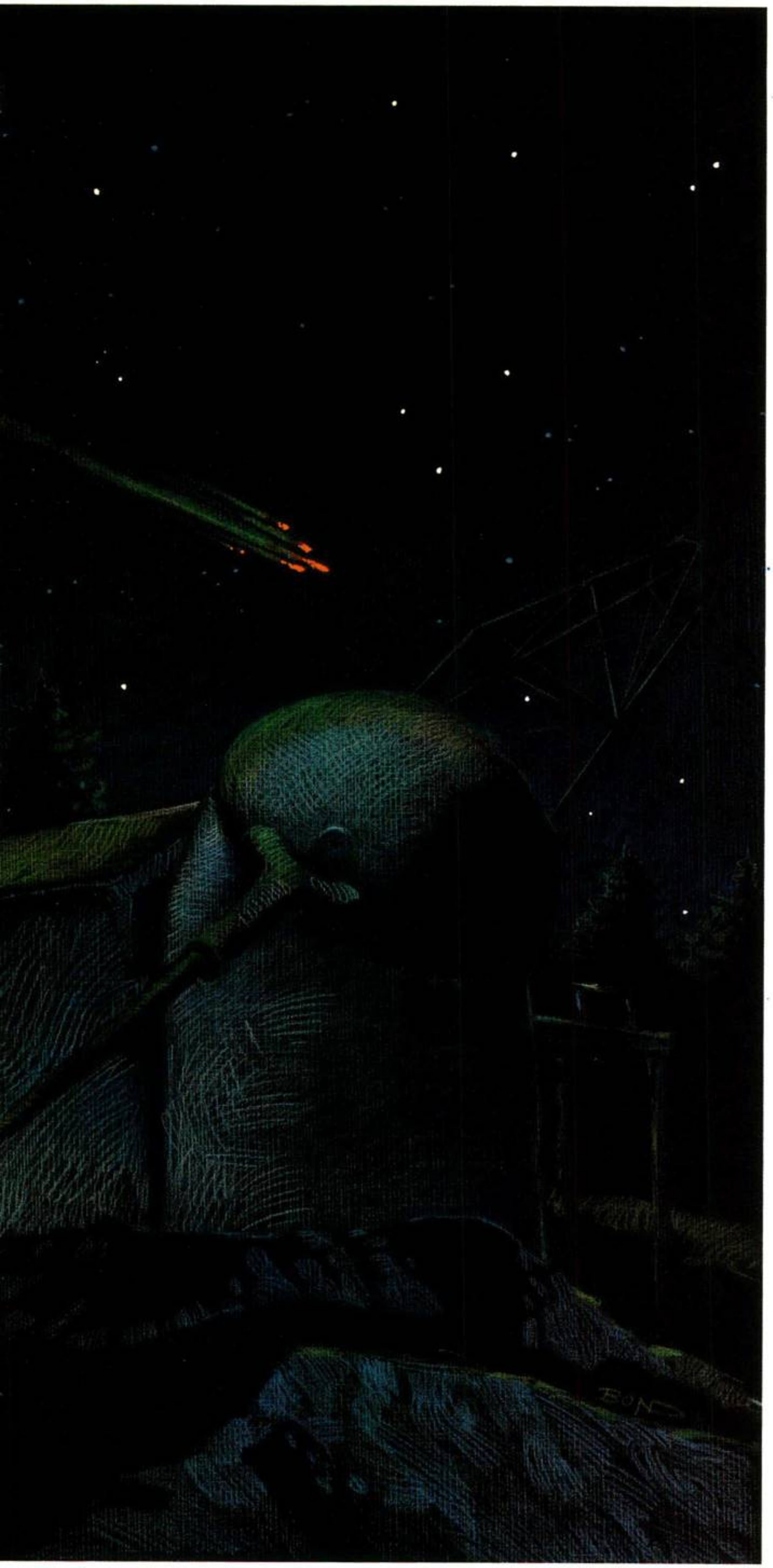
Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

It Came from Outer Space!

Is it a UFO? A burning plane? A fiery satellite re-entry? No, it's one of the sky's most memorable events — the brilliant trail of a vaporizing meteor.

by Christopher E. Spratt





What a great night! It's wonderfully dark, the kind of night you've waited months for — you and the many other people at tonight's star party. You're glued to the eyepiece, ferreting out faint nebulae along the Milky Way, when without warning the ground lights up a ghostly green.

You wheel around as fast as you can, and there it is — the fireball of a lifetime.

Its apparent diameter is now the size of the Moon; it has a teardrop shape with a shimmering tail streaming off the fiery head. The fireball is as bright as the Full Moon and casts an eerie light over the field of telescopes and enthralled observers. At the end of the flight the fireball breaks into a cascade of sparks. It looks like the sparklers children enjoy at fireworks displays. Except, this is better than any fireworks you've ever seen.

Then, unexpectedly, a sharp crack shakes the windows in the nearby house. The fireball then fades from sight, leaving only a softly glowing smoky trail. Finally, a dull rumbling sound rolls over the field, lasting perhaps 30 seconds.

The display is over. You think, "This is one sight I'll never forget!" Or will you? How long did the fireball last? What color was it? What altitude was it? Did you make any notes at all? If you did, you could help locate a visitor from outer space.

They're Big, They're Bright, They're Bolides

Each year between 20,000 to 100,000 tons of interplanetary material rains down on Earth. Most is in the form of fragile dust which burns up harmlessly in the atmosphere. You can see evidence of this destruction as brief streaks of light in the night sky. Called "shooting stars," these streaks are actually meteoric dust particles shooting through the atmosphere and glowing with the heat of their passage. Most of these meteors are no brighter than a dim star.

But watch the sky on enough nights and you'll see an occasional spectacular meteor, one that rivals the brightest planets or perhaps even lights up the ground. Meteors brighter than magnitude –4 are called fireballs. Astronomers have chosen this dividing line because magnitude –4 is about the brightness of the planet Venus when it's at greatest brilliancy, so it provides a standard that most observers can remember.

The sight of a fireball can be startling, not only because of its brilliance but also because of its vivid color. Fireballs can be green, yellow, orange, blue, red, as well as brilliant white. The light of a fireball comes from the glowing gas surrounding the solid meteoroid, rather than from the meteoroid itself. The gas is a mixture of vaporized material from the meteoroid and intensely heated molecules from the atmosphere. Each element glows with its characteristic set of colors. The eerie green light so common in many fireballs comes from atmospheric oxygen. Nitrogen from our atmosphere contributes blue, while sodium from the meteoroid can add yellow to the light. Magnesium, iron, calcium, and dozens of other elements add their own colors.

In general, fast-moving fireballs will tend to be white (a mixture of colors from many vaporized elements) while slow movers tend to be red. Many fireballs change color as they descend and brake from their initial cosmic velocity.

A magnitude –4 fireball can come from a pebble of iron or stone weighing barely an ounce. To create a typical –12-magnitude fireball requires an object weighing about 5 to 10 pounds. Astronomers have found that a fireball usually must be brighter than magnitude –8 for there to be any real chance that a piece will survive to reach the surface. The brightest fireball on record appeared over Sumava, Czechoslovakia, on December 4, 1974. Observers estimated its magnitude as an astounding –22! This is nearly as bright as the Sun. Surprisingly, nothing was ever recovered from this object. This is often the case with the super-bright fireballs — they shatter into tiny fragments which, even if they survive to the surface, are very difficult to locate.

An exploding fireball of any magnitude is technically called a "bolide," from the Greek *bolides*, meaning "a thrown spear." When less brilliant fireballs explode near the end of their flight, the meteoric debris from the fall can scatter in tens or hundreds of fragments spread over a wide area.

The fallen fragments of a bolide, called "meteorites," are one of the best sources of pristine interplanetary material. Finding this material is certainly cheaper than launching a space probe to the asteroid belt, which is where most fireball-forming objects come from. The meteorites that result from fireballs are probably bits of asteroids, rocky worlds that orbit the Sun between Mars and Jupiter. Collisions between asteroids create debris that scatters in odd directions. Some of this debris ends up in orbits that intersect Earth's path around the Sun. Once in the right orbit, it's only a matter of time before the debris collides with Earth in a fiery display.

For this reason, freshly fallen meteorites are of great scientific value. True, scientists have found ancient meteorites in abundance on the Antarctic ice. But these samples are not readily available to researchers, and traveling to Antarctica to get new samples is time consuming and expensive. Compared to ancient falls like the Antarctic finds, newly fallen meteorites are free of terrestrial contamination and the effects of weathering. This allows geochemists to measure accurately the relative abundance of trace elements (including organic compounds) to determine the meteorite's age. For these reasons, astronomers and geologists are still very interested in locating fallen meteorites. The key to recovery is an accurate report of the fireball.

Airline pilots have veered their planes off course to avoid mid-air collisions with bolides.

But Officer, I Know Where It Landed!

A spectacular fireball can be seen over a radius of 200 miles or more. Such an event, especially if it occurs in the early evening, generates reports from thousands of well-meaning witnesses. Many observers are certain they know exactly where the meteor fell. Inevitably, some people, startled by the unexpected bright light, will claim, "I had to drive off the road to avoid hitting the ball of fire." Convinced the meteor whizzed by only a few hundred feet away, eyewitnesses often insist that all scientists have to do is search the neighboring field and they will be sure to find a smoking meteorite at the bottom of a crater.

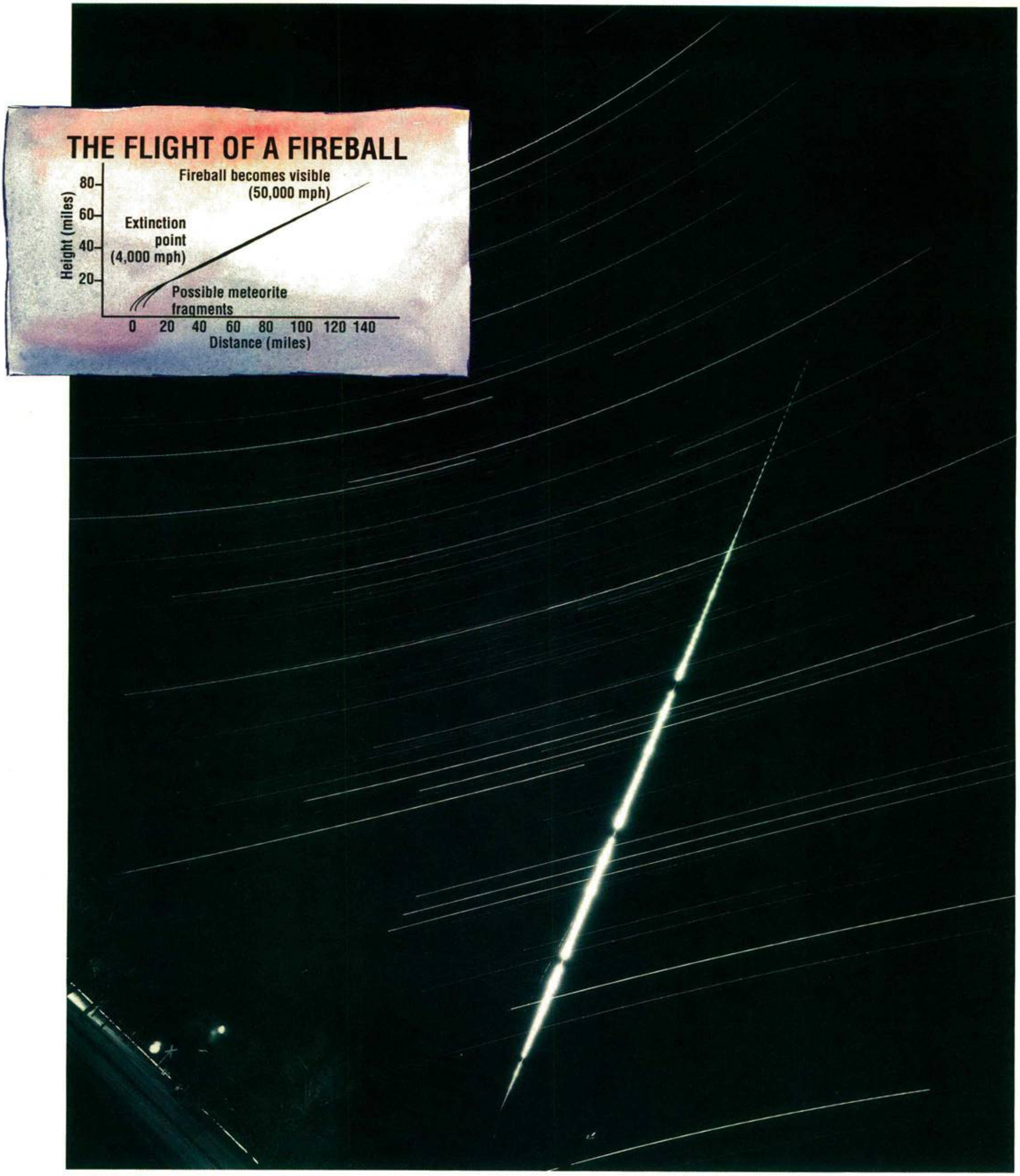
Unfortunately, locating a meteorite is rarely that easy. For one thing, when it is visible as a fireball, the meteor (and perhaps meteorite-to-be) is still tens of miles high. The great altitude surprises most people; when a bright object like a meteor streaks across the night sky for a few brief moments, the illusion of closeness fools even well-trained professionals. Airline pilots have mistakenly veered their craft off course to avoid mid-air collisions with bolides, objects that research later revealed were 50 to 100 miles away and perhaps 20 miles higher than the aircraft.

The fact is that a typical fireball first appears at a height of about 80 miles. (By comparison, the highest jets fly at about 12 miles.) The visible fireball usually extinguishes at a height of about 12 miles. At this altitude the denser atmosphere slows the meteoroid's descent to the point where it is no longer traveling fast enough to generate light. The meteoroid has lost all its initial cosmic velocity and from that point on is simply free-falling.

It is at the end of the visible fireball path that you often see explosions. The shock of hitting the denser atmosphere causes the meteor to fragment into several pieces. This point in the fireball's trajectory is called the "retardation point." The altitude of the retardation point can vary considerably from fireball to fireball. Determining the exact altitude of the break-up and burn-out can help indicate the mass and composition of the incoming meteoroid.

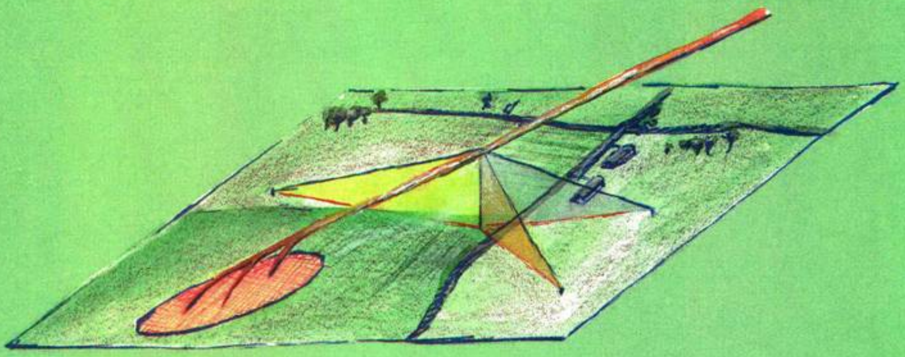
Fireballs that manage to penetrate as far down as 12 to 15 miles above Earth's surface are most likely to drop meteorites. Researchers have estimated that the time for a meteorite to reach the ground in a downward-curving path from a height of, say, 13 miles is about 3 to 4 minutes. During that time, the fragments, now dark and invisible, can travel tens of miles. The distance between the burn-out point and the impact area depends on a fragment's mass, velocity, and the angle of its fall.

In general, in order for the meteorite to survive passage through the atmosphere, its initial entry velocity should not exceed 14 miles per second (50,000 miles per hour). The object's material must also be strong enough to survive without extensive fragmentation. In addition, the amount of material vaporized off the meteoroid during the flight can't be too great. The meteoroid must survive until it has decelerated to less than 5 to 6 miles per second (about 20,000 miles per hour). Even meteoroids estimated to have been very large have disintegrated completely. Often all that is left of a magnitude –20 fireball is a great deal of dust. It seems that many spectacular fireballs are very fragile, comet-like "dust-balls."


THE FLIGHT OF A FIREBALL
Fireball becomes visible
(50,000 mph)
Extinction
point
(4,000 mph)
Possible meteorite
fragments
Height (miles)
80
60
40
20
0
20
40
60
80
100
120
140
Distance (miles)

THE SKY LIT UP on January 3, 1973, when the Lost City fireball swept over Oklahoma. Searchers recovered 38 pounds of stony meteorites. Typical fireballs like Lost City start burning at an altitude of about 80 miles and extinguish 12 to 15 miles up, sometimes in a final explosive burst. Photo courtesy Smithsonian Observatory.

If You See a Fireball



THE GREAT ALTITUDE of most fireballs means they can be seen over a wide area. Combining reports of the fireball's altitude and azimuth from observers on different sides of the flight path enables researchers to fix the location of the path and possible fall area. Illustration by Tom Hunt.

If you see a fireball your report may be just the one needed to add certainty to a doubtful path. Here's what you should note:

Circumstance: At what time, to the nearest minute, did the fireball appear? Compare your watch with an accurate clock or time signal as soon as possible. Note your exact location (longitude and latitude if possible). Were you standing still, walking, riding in a car or a boat, or looking out the window when you made the observation?

Position: What was the altitude and azimuth angle of the beginning and end points of the fireball's path? The horizon is at 0° altitude, halfway up the sky is 45°, and directly overhead 90°. Due north is 0° azimuth, east is 90°, south is 180°, and west is 270°. If possible, plot the position of the path against the star background. If there are no stars visible (it's daytime), try to line up the path with identifiable landscape objects, or try to note the fireball's path

It Was as Bright as the Sun

If you are fortunate you may see a fireball in broad daylight. Some of these super-bright fireballs have cast daytime shadows. Some have rivalled the Sun. Daylight fireballs will often leave behind what look like smoke trails. Depending on the angle of the Sun, this trail can appear reddish or grey-black. The trail is made of dust ablated off the surface of the meteoroid during its flight. A nighttime fireball will also leave a trail. However, at night the dust trail is usually invisible. Instead, you see a softly glowing luminescent trail composed of ionized molecules from the atmosphere.

Both types of trails can last for several minutes, and in extreme cases over an hour or more. Dust trails usually form at lower altitudes (25 to 40 miles) than ionization trails and can move under the influence of stratospheric currents, after a time assuming a characteristic zigzag form.

While meteorites can fall at any time of the day and of the year, there are peak times for reports of bright fireballs. Mid-afternoon (around 3:00 p.m.) in the summer (May to August) seems to be a popular time for spotting daylight fireballs. This is probably due to the fact that more people are outside at that time. In addition, many great falls have occurred in the month of February, while March and December have the least number of observed falls. There is also a tendency for a certain class of meteorite, called an ordinary chondrite, to fall more often in the afternoon. In the 1960s one researcher found that this pattern is what would be expected if the meteorites came from a short-period comet or asteroid with an aphelion near Jupiter. However, any preferences for meteorites to fall in certain months and at specific times of the day may indeed be just a fluke of statistics.

Because meteorites are cold, dark objects by the time they reach lower altitudes, the only chance of seeing one actually fall to the ground is likely to be from one of the rare daylight fireballs. On August 2, 1946, ranch hands in Texas made just such a sighting when they saw the Pena Blanca Spring meteorite fall into a pond.

It Was So Close I Could Smell It

Even more unusual are reports of people actually smelling the passage of a fireball. Witnesses often describe the odor as sulfurous. The smell of sulfur was first mentioned in an account of a fireball in Virgil's *Aeneid,* and also in a much later account of a shower of stones near Crema, Italy, in 1511. On even rarer occasions, observers will report smells like "hot metal" or "raw fish" or even "onion-like."

Better documented but still not entirely explained are the reports of meteor sounds. In fact, there are well-documented cases of meteor sounds dating back to 817 A.D. Some observers have claimed to have heard sounds simultaneously with seeing the fireball even though they may be over a hundred miles away from the flight path. Since this is far too great a distance for the sound to travel while the fireball is visible, these noises have been called "anomalous." They appear to be transmitted at the speed of light. (A fireball accompanied by such anomalous sounds is sometimes called an electrophonic fireball.)

Some scientists feel that a form of electromagnetic radiation, perhaps very low frequency radio waves, could be generating the sounds. After all, fireballs convert their kinetic energy of motion into visible light, which occupies only a small portion of the spectrum. Perhaps they also generate radio waves.

In some instances, anomalous meteor sounds, described as whooshing or hissing noises, have been reported by people close to metal conductors. The metal may be acting as an antenna and diode converting the radio waves into audio waves.

Another type of sound sometimes reported with large bolides is a loud detonation resembling cannon fire, shotgun fire, or thunder. These sounds are real and come from an atmospheric shock wave similar to those generated by supersonic aircraft. These sounds can be heard over a very large area, up to a 40-mile radius or greater. This sound area sometimes has *"zones of silence"* — several distinct zones of audibility separated by areas of silence. This in relation to compass direction and altitude. If you're using a compass, state any correction applied for magnetic deviation.

Brightness: How bright and how large was the fireball? For comparison Venus is usually magnitude –4, the three-day-old crescent Moon is –7, the First Quarter Moon is –10, and the Full Moon is –12.5 and is 0.5 degrees across. A daylight fireball will be on the order of –20 or so.

Duration: How long did the fireball last? This is where observers make the greatest errors. Few people have the presence of mind to start counting off seconds as soon as a fireball bursts into view.

Appearance: What shape was the fireball? Did it appear to fragment on the way down? Note the color of any sparks as well as the main color of the fireball. Did it change colors?

Aftereffects: Was a luminous trail or smoke cloud visible? How long did it last? Which direction did it drift? How fast?

Sounds: How much time elapsed between the first appearance of the light and the arrival of the first sound? What was the sound like? How long did it last? If you hear sounds like hissing, note your hair length, the type of clothing worn, frame material of your glasses, and any metal structures or electrical conductors in the vicinity.

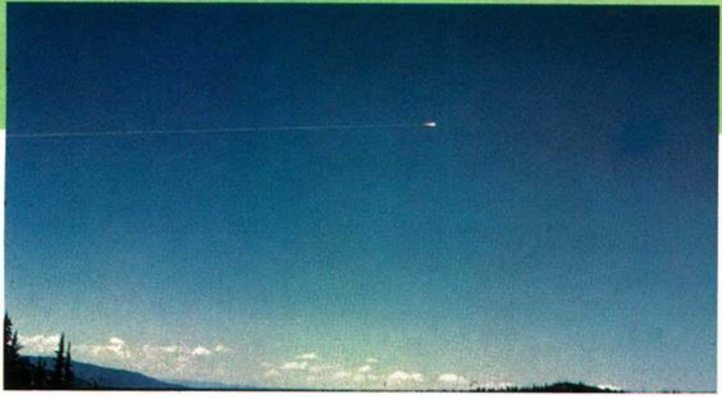
Meteorological: Note the temperature and relative humidity. Was there a wind blowing? From what direction and strength? If possible record the barometric pressure, especially if you hear anomalous sounds.

Smell: Was there any distinct smell? Did the smell appear to persist and if so for how long?

You should report spectacular fireballs, especially those brighter than magnitude –8, right away. Write or call your local astronomy club, planetarium, or observatory. In the United States observers can also mail reports to the Scientific Event Alert Network (SEAN) at the Smithsonian Institution, Natural History Building, Washington, D.C. 20560. SEAN is a clearinghouse which alerts scientists to terrestrial phenomena such as volcanic eruptions, earthquakes, fireballs, and meteorite strikes.

In Canada, you can phone or mail reports to Dr. Ian Halliday of the National Research Council, Herzberg Institute of Astrophysics, Ottawa K1A 0R6; phone (613) 990-0704 during working hours (Eastern Time).

In Britain, contact the British Astronomical Association's head office at Burlington House, Picadilly, London W1V 9AG; phone (071) 734-4145.



A NOW FAMOUS FIREBALL streaked across the daytime sky on August 10, 1972. Seen over Wyoming, Idaho, and Montana, this remarkable object, estimated to be as large as a house, skipped back into space. Photo by Lanny Ream.

phenomenon has also been noticed with distant artillery fire. In both cases, the zones of silence are caused by the refraction and reflection of the sound by the atmosphere.

On rare occasions, very large fireballs can actually shake buildings. Window panes rattle and sometimes break, bells tinkle, dishes rattle, doors and windows open, bookshelves vibrate, suspended items sway. In some cases, the passage of a bolide can mimic the effects of a small earthquake. These vibrations only occur near the fall point of a meteorite and are a sign that a meteorite may be nearby.

Some fireballs have even produced a seismic record. Sometimes this is from the actual thud of an impact, but more frequently it is from a sound wave. In other words, the fireball's sonic shockwave generated a seismic disturbance large enough for nearby instruments to detect it.

It's Down!

Near impact sites, observers often report whistling or humming sounds, presumably caused during the last few moments of flight, followed by a thud or thuds from the impact. The landing of a meteorite takes place without any light phenomena, the meteorite having long ceased glowing.

The speed at which a meteorite falls to Earth varies. It depends on the mass of the object, its trajectory, its composition, the amount of atmospheric friction, and even the time of day. Most recovered meteorites are usually in the 10- to 15-pound range. They hit with a final velocity of about 200 miles per hour — essentially the speed any rock would have if dropped from a height of a few miles.

At this speed most meteorites do not produce gaping craters. If the ground is soft the meteorite may dig itself in as deep as 6 feet. In many cases, however, searchers find freshly fallen meteorites sitting right on the surface. If the meteorite fragmented on the way down, the many pieces will hit over an elliptical area that is elongated along the flight path. The elliptical shape of this so-called "strewnfield" is a result of atmospheric drag slowing down the small pieces of debris more than the larger ones. The biggest chunks of meteorite fragments land farthest along the direction of flight. Some falls produce a rich load of fragments scattered along a strewnfield several miles long. The stony-type meteorite that fragmented over Holbrook, Arizona, in 1912 produced over 16,000 small fragments. Such a fall is a meteorite-hunter's dream.

Unfortunately, even avid meteorite trackers get few opportunities to pursue their quarry. Estimates indicate that only one percent of bright fireballs drop meteorites. Nevertheless, if you spend a great deal of time outdoors at night, you will probably see several truly spectacular fireballs in your lifetime. By good fortune one of those could be the source of valuable pieces of interplanetary debris. By being informed, you could help pinpoint one of these meteorites when the unexpected bursts forth out of the sky. ☐

Christopher E. Spratt is a Canadian amateur astronomer with a special interest in meteorites. His last article for ASTRONOMY was "On The Trail of a Meteorite" in August 1989.

New Visions from CCDs

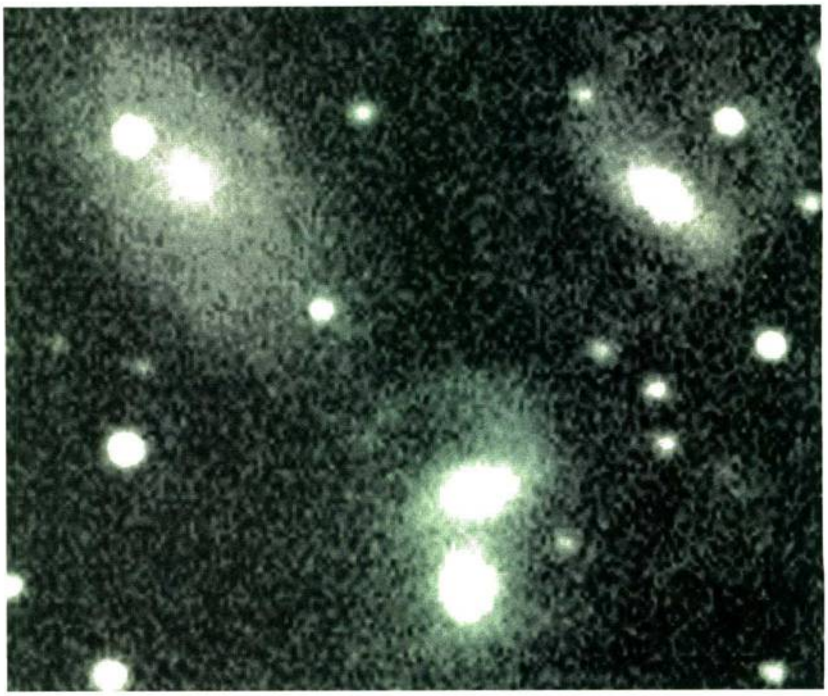
Charge-coupled devices are making astronomical images child's play to record and manipulate — and the results are both information-packed and dazzling.

by David J. Eicher

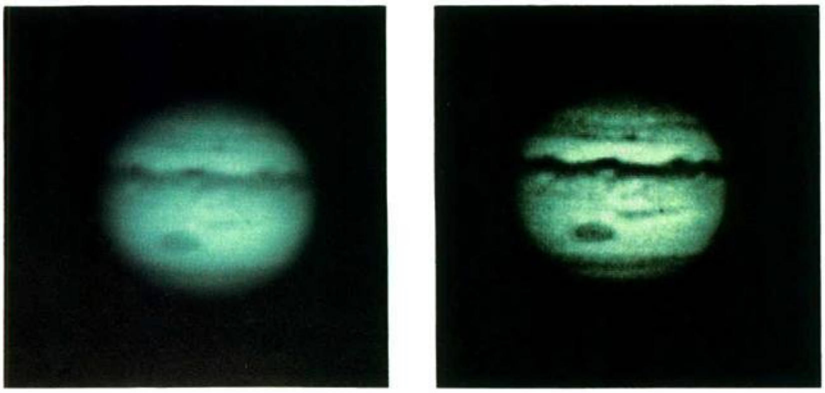
Larry Myers sat in front of a glowing screen in his home in Elk Grove, California. He quipped, "Is a histogram anything like a candygram?" Like a growing number of astrophotographers, Myers is getting used to sitting in front of an IBM or Macintosh instead of standing in the darkroom in front of an array of trays and chemicals. Last summer Myers was swept up in a wave of interest surrounding charge-coupled cameras, powerful devices that are revolutionizing the ways amateurs record — and manipulate — images of celestial objects. In use by professional astronomers for 20 years, CCDs are now inexpensive enough to attract amateurs. (See "CCD Cameras: Digital Astrophotography is Here" by Michael Chibnik, October 1990.)

Myers' experience with CCDs illustrates the great differences between electronic imaging and recording objects on film, however. The start of the process — the acquisition of the image — is much easier with CCDs because their great sensitivity means that exposures can be relatively short, from a few seconds to five minutes. Consequently, many of the traditional pitfalls of astrophotography, including guiding errors and polar alignment, are much less critical than they would be for, say, a two-hour exposure on conventional film. CCDs also capture a wide dynamic range, allowing processing that shows both bright and faint details in a single finished image.

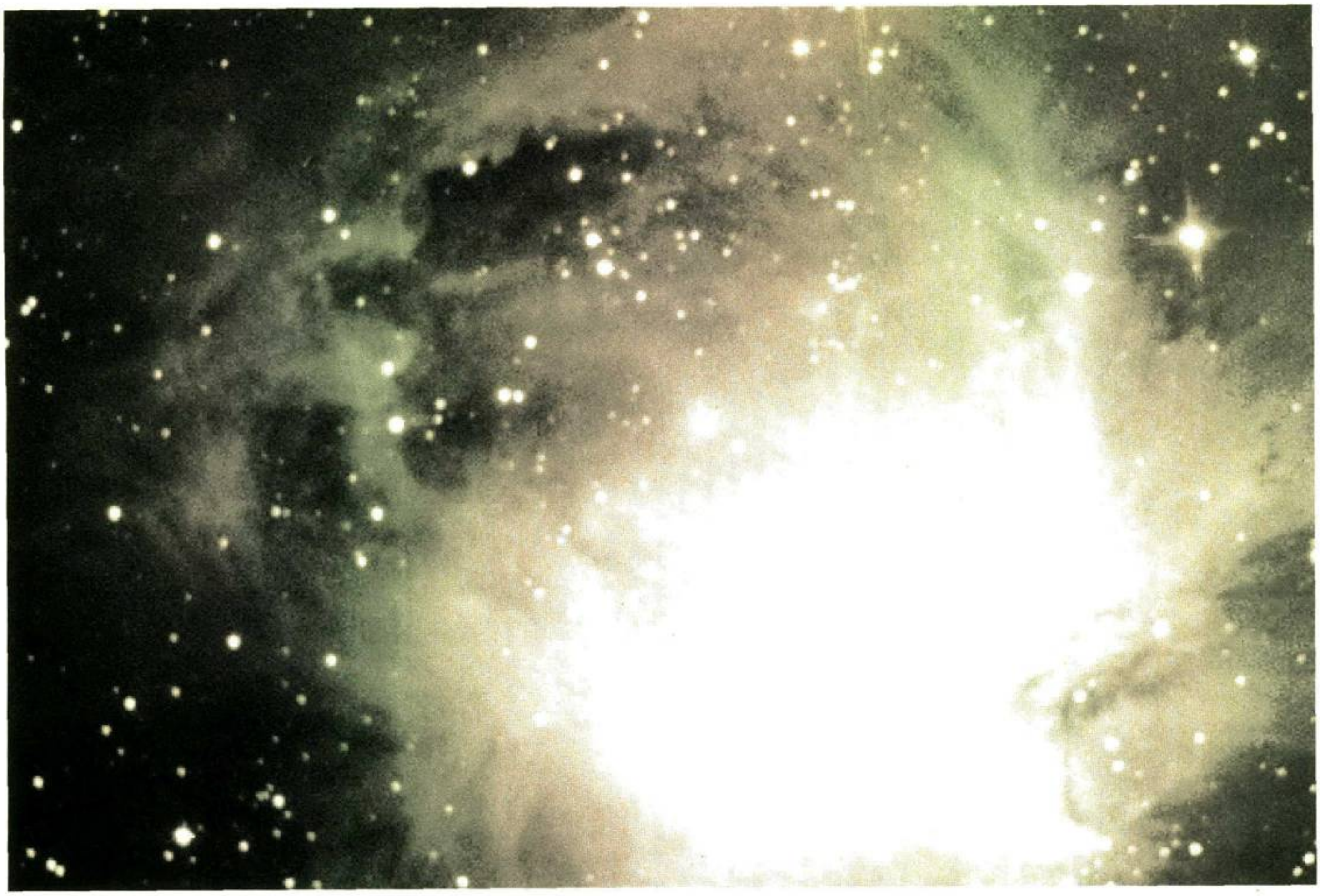
More importantly, however, CCDs allow much more control of the image after it has been recorded than a darkroom could provide. The data in a CCD image are quantified much more precisely than the data in a normal photo. A CCD image contains far fewer "pixels" than a continuous tone, high-resolution photo,



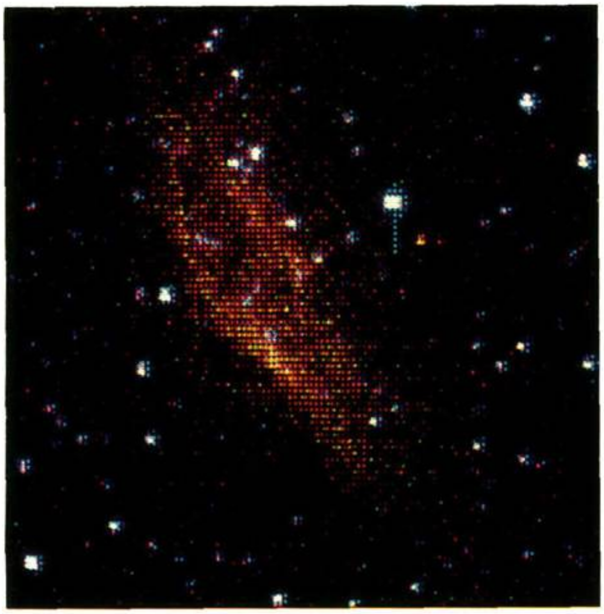
THE GREAT SENSITIVITY of CCD cameras allows them to capture faint details in short exposures. This image by Jack Newton (25-inch reflector, SBIG ST-4 CCD camera, 300-second exposure) shows Stephan's Quintet, a faint cluster of galaxies in Pegasus.



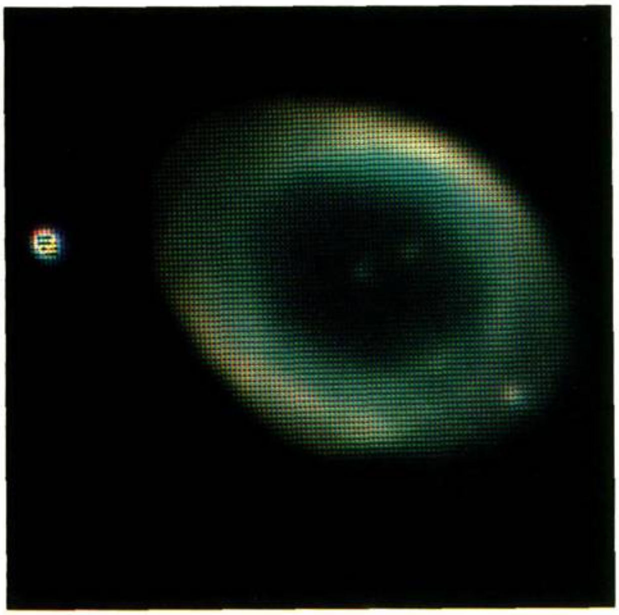
TWO IMAGES OF JUPITER reveal processing enhancements made to conventional photographs after they were scanned into a computer using a *CCD* camera. The left-hand image is a normal image processed for maximum detail; the right-hand image is contrast enhanced and shows more small details. Photos by Don Parker.



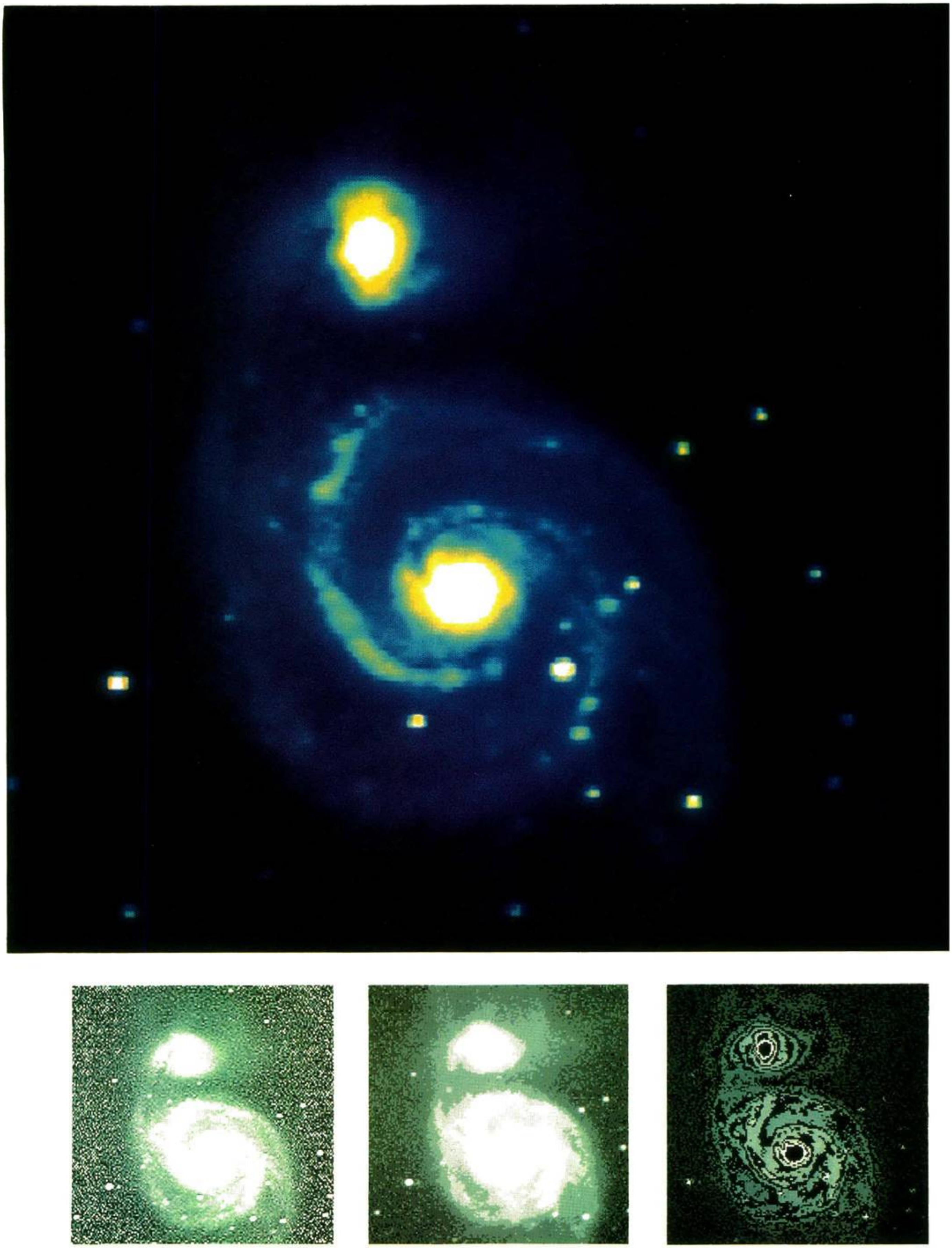
FAINT OUTER WISPS of nebulosity were captured in this CCD image of M42, the Orion Nebula. Image by Richard Berry (6-inch f/5 reflector, Photometrics Star IA CCD camera, 300-second exposure).



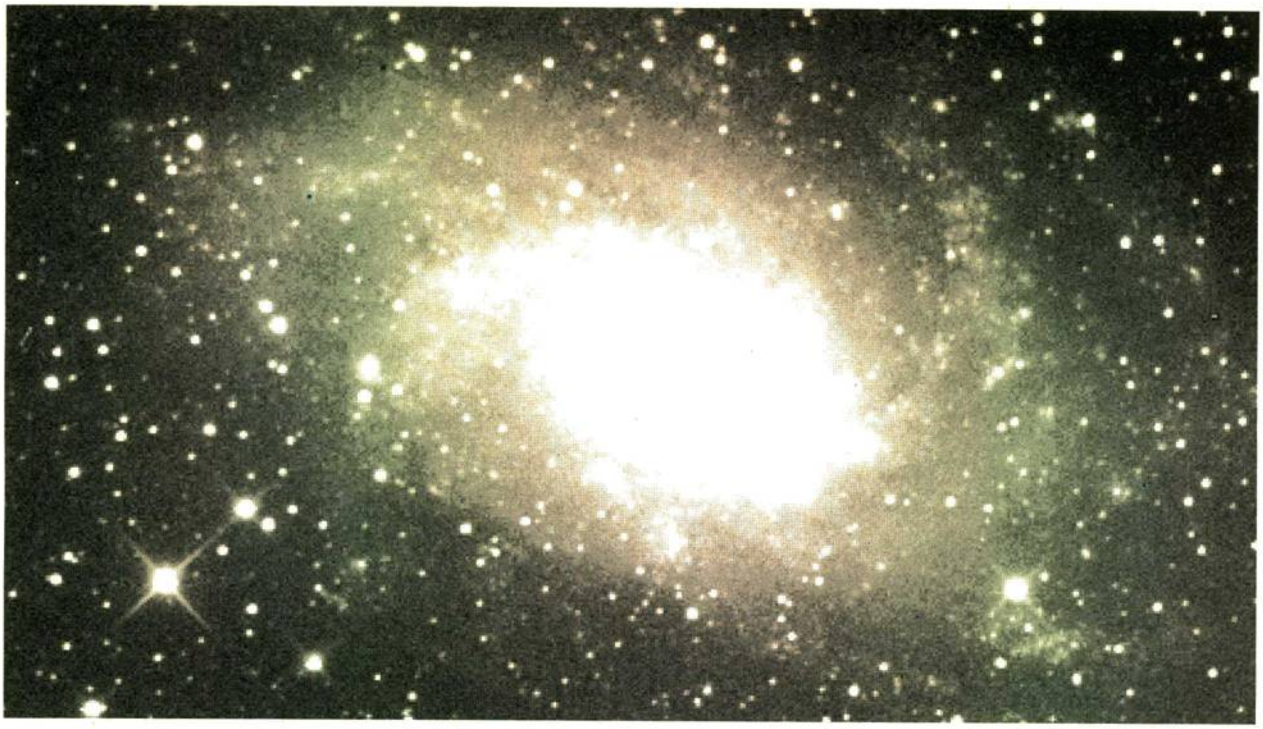
MODEST EQUIPMENT records powerful images of faint deep-sky objects when coupled with a CCD camera. This image of the California Nebula is a color composite made with a 28mm lens and a 600-second exposure. Image by Richard Berry.



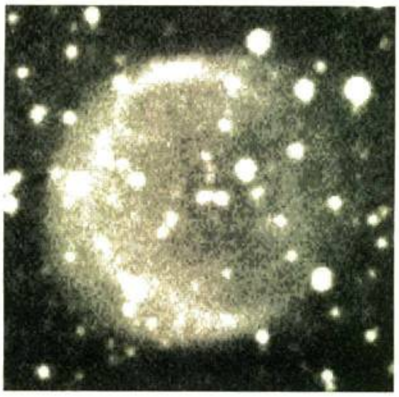
SUBTLE, NATURAL COLORS can be produced by adding together three images made in the primary colors. Three images by Jack Newton were combined into this true-color image (25-inch reflector, SBIG ST-4 CCD camera, 300-second exposures).



POWERFUL IMAGE PROCESSING is now possible with CCD technology and a home computer. These images of M51 were processed to show a straight "maximum detail" image (bottom left), a posterized step-wise scaling (bottom center), a contour scaling (bottom right), and a false-color palette (top). Images by Patterson Electronics, 8" SCT, SS700 camera, 120-second exposure.



EXPOSURE TIMES ARE SHORT with CCD cameras. This image of the galaxy M33 in Triangulum is a 300-second exposure with a Star IA CCD camera by Richard Berry. It shows stars as faint as those captured in a 90-minute photographic exposure.



LOW-CONTRAST OBJECTS that show up poorly on film do well in CCD images. This image shows the 1'-diameter planetary nebula NGC 6781 in Aquila. Image by Jack Newton (25-inch reflector, SBIG ST-4 CCD camera, 300-second exposure).

but the data present are recorded — and can be retrieved — with far greater precision. Essentially a CCD camera and a PC form an image-processing laboratory that offers dramatic possibilities limited only by the tinkering skills of the user.

The possibilities for amateur astronomers are nearly endless. CCDs enable you to produce striking images of deep-sky objects that show the ghostlike subtleness of a galaxy's spiral arms *and* the inner details of a galaxy's nuclear region. Photography does not allow this, overexposing the central regions of bright objects in order to record faint, outer regions. Thus, CCD cameras allow you to produce ideal portraits of objects with a large range of brightness.

Project-oriented observers will have a field day with CCDs. Planetary imaging will become easier, as frames that show maximum clarity because of moments of crisp seeing can be grabbed and processed to show low-contrast details. Also, you can keep imaging until you get good frames, because you see the results right away. Sequences of planetary images could reveal small, rapidly changing features on the surfaces or in the clouds of some planets, most notably Mars and Jupiter. Imaging small objects such as planets, galaxy clusters, and planetary nebulae is more efficient with CCDs than with photography. Traditional photographic films capture and convert only about 2 percent of incoming photons into the image. By contrast, CCDs convert approximately 50 percent of the incoming photons into signal. The trade off with photography is that you get a small amount of highly precise data rather than a large amount of relatively crude information, and the CCD information is in digital form and easy to process.

Accurate measurements of double star separations and position angles will become routine for CCD users. The Santa Barbara Instrument Group, one manufacturer of CCD cameras, includes software for this purpose. Photometric applications like measuring the brightness of variable stars and variable galaxies, checking for lunar transient phenomena, and even capturing galaxy frames to search for supernovae are all possible, given the software to easily compare and measure brightness and position.

CCDs are not the be-all and the end-all, however. Although costs for a capable unit have dropped drastically, they are still relatively expensive. The investment you must make learning how to use CCDs and process the images — the learning curve — is steep. Image manipulation requires patience and practice in order to achieve optimum results. But a digital processing lab in everyone's study means that it is so easy to corrupt data that the line between what is real and what is fake is fragile and easy to cross.

Despite the expenses and risks, CCDs represent a powerful new capability for amateur astronomers. They are clearly marking the path down which astronomical imaging will follow. Myers summarizes the attitude of most astrophotographers when he says "CCD imaging is essentially a technological extension of film-type astrophotography, so why should I feel threatened by new things? I'm having more fun now than I ever have. I think CCDs are the sweetest news for astrophotographers in years — the best candygram I've ever seen." ☐

ASTRONOMY Tests Ten Nebula Filters

Of the many filters on the market all promise to reduce the effects of light pollution and enhance deep-sky viewing. We fieldtested ten filters and found significant differences among them.

by Alister Ling and Jerry Spevak

Nebula filters can dramatically improve the view of deep-sky objects through your telescope. When you pop in one of these silvery devices it's as if you were magically transported into country skies, or acquired a bigger telescope.

However, no filter can make an object appear brighter. Rather, nebula filters (also called light-pollution reduction, or LPR, filters) make the background darker. They enhance deep-sky views by increasing the contrast between object and sky. Since they were first introduced in the late 1970s, nebula filters have become essential accessories for deep-sky observers.

SkyGlow™ UltraBlock™ JAPAN
ORION SkyGlow
ESTRON®

A Flock of Filters

No one filter is the best for all types of observing, a fact we readily confirmed when testing the ten filters for this review. We divided the filters into three varieties:

Broadband Filters: These filters block blue and yellow light and transmit a wide band of light in the green portion of the spectrum. The width of this transmission band varies from 90 nanometers (nm) to 40 nm, depending on the filter. Filters in this category are often advertised as being useful not only for emission nebulae but also for objects that emit light over a continuous spectrum. This includes galaxies, reflection nebulae, and star clusters.

However, any broadband design is a compromise. None can offer dramatic contrast between object and sky. If a filter is transmitting enough light to allow you to see stars, clusters, galaxies, and blue reflection nebulae, it can do so only by sacrificing some degree of light pollution reduction. Its bandpass is still wide enough to allow unwanted light through.

Broadband filters work best in moderately light-polluted skies. From severely polluted urban sites a broadband filter will provide some measure of sky darkening, but not as great as with narrowband filters.

Narrowband Filters: While a broadband filter will improve the view of emission and planetary nebulae, why not create a filter tailored to the spectra of these objects? Since nebulae produce light at only a few narrow wavelengths, there is no need for a broad green transmission window. Only the region of the emission lines from hydrogen beta (at 486.1 nm) and doubly ionized oxygen (at 495.9 and 500.7 nm) needs to be passed. This is the rationale of narrowband filters. These models feature a bandpass about half the width of the broadbands. They cut out most light-pollution lines and much of the continuous spectrum from stars and galaxies. As a result they provide dark skies but are of little use on objects other than emission and planetary nebulae.

Line Filters: At least one company offers filters that go one step further. These "line filters" have transmission windows that are so narrow they allow only one or two nebular emission lines through. Line filters allow the observer to isolate this one bright line, and at the same time block as much light pollution — artificial and natural — as possible.

A First Inspection

We bought all the filters from independent dealers where possible (some had to purchased direct from the manufacturer). All were 1 1/4" models. Where manufacturers offered "premium" models we purchased those.

Before embarking on the visual tests, we gave each filter the once over. By holding each filter up to a window, we looked for any thin rings or crescents of uncoated glass around the perimeter of the filter. While we found these coating flaws did not affect performance in practice, at $70 to $100 apiece a filter should not have cosmetic defects. Although they might have been isolated examples that slipped through quality control, the Celestron, Meade, and Orion filters had uncoated crescents visible, while the Parks filter rattled in its retaining cell.

We were also surprised that some filters were unlabeled. Only the

THE FILTERS WE TESTED

Filter:
LPR Type A $84.00
Manufacturer:
Celestron International
2835 Columbia Street
Torrance, CA 90503
(800) 421-1526

Filter:
Daystar 300 $75.00
Manufacturer:
Daystar Filter Corporation
P.O. Box 1290
Pomona, CA 91769
(714) 591-4673

Filters:
Premium Deep-Sky $79.50
Premium UHC $99.50
Premium OIII $99.50
Premium H-Beta $99.50
Manufacturer:
Lumicon, Inc.
2111 Research Drive, #5A
Livermore, CA 94550

Filter:
Meade Model #908 $69.00
Manufacturer:
Meade Instruments Corporation
1675 Toronto Way
Costa Mesa, CA 92626
(714) 556-2291

Filters:
SkyGlow Broadband $59.95
SkyGlow UltraBlock $79.50
Manufacturer:
Orion Telescope Center
2450 17th Avenue
P.O. Box 1158-A
Santa Cruz, CA 95061
(800) 447-1001
(in California (800) 443-1001)

Filter:
Parks LPB $79.00
Manufacturer:
Parks Optical Corporation
270 Easy Street
Simi Valley, CA 93065
(805) 522-6722

Prices are what we paid from the dealer or manufacturer.

Filter Wheel Supplier:
Optical Research Corporation
3009 East Forest
Appleton, WI 54915
(414) 734-5006

Celestron, Orion, and Parks models were clearly marked with white lettering to identify the filter, something we consider a significant convenience when handling filters in the dark. In particular, we were surprised that the Lumicon filters (the highest priced units we tested) had no distinguishing labels.

Most of the filters came in plastic cases, either small square boxes or cases similar to the "jewelbox" kind supplied with camera filters. The Meade filter was an exception. It came wrapped in a plastic bag stuffed into a tiny cardboard box — poor packaging, we thought, for a $70 filter. Only the Orion filters came with test charts showing the spectral response of each filter.

The Test Procedures

We tested each filter visually and then with a spectrophotometer to measure its spectral response. To avoid being swayed by the results of the lab tests, we conducted these after performing the visual tests at the telescope.

We placed the filters in a rotary filter holder at random. (We used a Multi-Filter Wheel on loan to us from Optical Research Corporation.) We were able to quickly spin through seven filters, while leaving one hole blank to check the unfiltered sky. We each took turns going through a set of filters. Each observer was never aware of which filter was in place — we simply used a numbering system which we matched up to names later on. Another observer, Bruce McCurdy, helped us out with some of the testing. We gave a filter a positive or negative rating only if there was complete agreement among the observers; a disagreement meant the differences were too close to call.

To ensure our visual tests would match typical observing conditions, we used a range of instruments under different sky conditions. A schoolyard park in metropolitan Toronto served as our city site. There were a few high-pressure sodium- and mercury-vapor streetlights nearby, representative of what many back-yard observers contend with. Overhead, stars of magnitude 4.5 were barely visible. To the south, Sagittarius and Scorpius were swamped in the glow of the city. Our darker site lay 25 miles to the north. At that distance, the Great Rift in Cygnus and the Scutum starcloud in the summer Milky Way were easily visible. The limiting magnitude near the zenith was near 6.0, but again our view to the south of test objects like the Lagoon Nebula was affected by Toronto's glow. By pointing away from the city, we were looking at conditions similar to much darker skies.

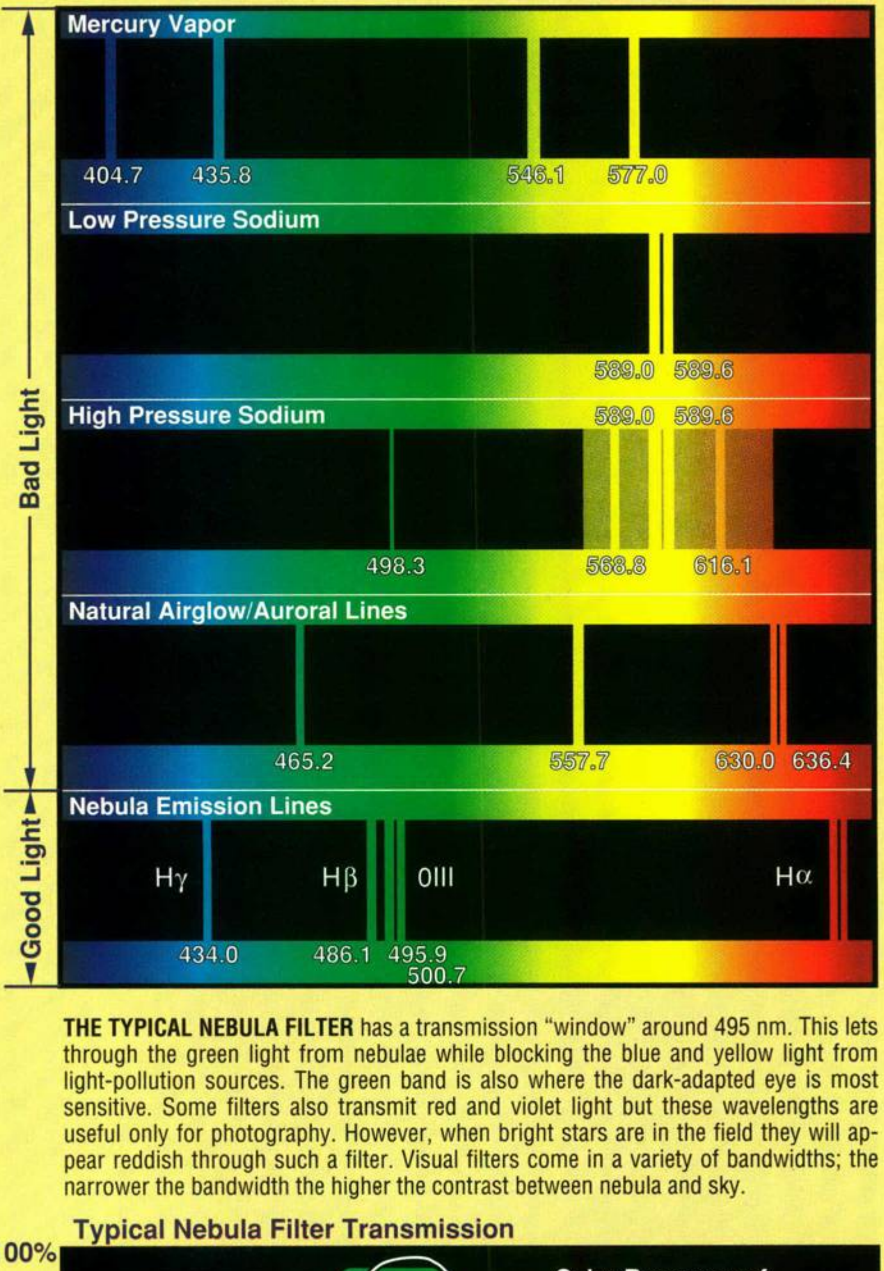
At each site we employed an observing hood to block out stray light, a technique we've found essential with nebula filters. The reason is that unlike conventional colored filters, nebula filters do not absorb unwanted light, they reflect it. Stray light entering the eyepiece from around your head can hit the shiny surface of the filter and reflect back into your eye, making it difficult to see the edge of the field and the object. This may explain why some observers have difficulty using nebula filters.

Our main test scopes were an 8-inch f/10 Schmidt-Cassegrain and a 12.5-inch f/5 closed-tube Newtonian reflector. We also used a 65mm f/6 refractor. We found that at every magnification the Newtonian consistently showed the best contrast gain. We feel this was due to the filters blocking the scattered light that is a common trait inside Newtonians. With better baffling and higher inherent contrast, the refractor and SCT both showed less contrast enhancement with the filters. In all cases, however, the relative differences among the filters remained consistent from one telescope to the next, giving us confidence that our ratings will apply no matter what telescope you own.

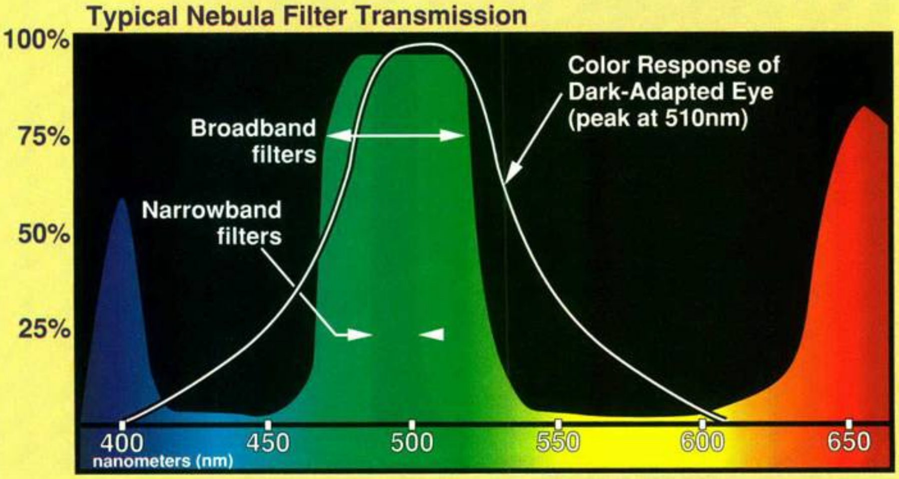
The Broadband Filters

This class of filters included the Celestron LPR, Daystar 300, Lumicon Deep-Sky, the Meade #908, Orion SkyGlow, and Parks LPB filters. All these models are advertised as general purpose LPR filters, and not as ultra-high-contrast specialty filters. We tested each on representative targets

How Nebula Filters Work



THE TYPICAL NEBULA FILTER has a transmission "window" around 495 nm. This lets through the green light from nebulae while blocking the blue and yellow light from light-pollution sources. The green band is also where the dark-adapted eye is most sensitive. Some filters also transmit red and violet light but these wavelengths are useful only for photography. However, when bright stars are in the field they will appear reddish through such a filter. Visual filters come in a variety of bandwidths; the narrower the bandwidth the higher the contrast between nebula and sky.



Light pollution is a composite of many sources. The spectrum of a typical urban sky shows a relatively weak continuous glow (a "continuum") spanning the entire visible range, from violet all the way to red. This background glow comes from incandescent light sources, like the tungsten lamp in the porch light your neighbor insists leaving on all night. Superimposed on this continuum glow are bright lines and bands. These come from mercury-vapor lights and from low- and high-pressure sodium lamps. Mercury-vapor sources (such as some streetlights and outdoor advertising lights) emit narrow lines in the yellow, yellow-green, and blue portions of the spectrum. Low-pressure sodium lamps emit only a narrow pair of lines in the yellow end. High-pressure sodium lamps, the worst offenders and the most common form of streetlight, emit a broader band of wavelengths from orange to yellow-green.

However, even a rural site has sky glow. From the darkest of sites the properly dark-adapted eye perceives the sky background as a very dark grey. The sources of this stray light are completely natural. They include sunlight scattering off dust particles near the Earth's orbit and light from "airglow," a form of fluorescence caused by charged particles recombining in the upper atmosphere.

LPR or "nebula" filters work by blocking out the bad light and letting through the good light. They transmit a select portion of the green spectrum while blocking unwanted blue and yellow light on either side of the desired emission lines. The principle emission lines from nebulae also happily coincide with the peak sensitivity of the dark-adapted human eye. While some filters also transmit red and violet light, on dim objects at night the eye is blind to these colors; these filter "windows" are useful only for photography.

For visual use, the difference between filters is mostly in the width of their green window. Broadband filters have a less dramatic sky darkening effect but are usable on a wide range of objects such as galaxies and clusters, as well as nebulae. Narrowband filters produce darker skies but can only be used on emission and planetary nebulae.

COMPARING THE FILTERS

Filter	Type	Measured Bandwidth in Green Light (at 50%)	(at 70%)	Measured Maximum Transmission
Orion SkyGlow	Broadband	85 nm	80 nm	96%
Lumicon Deep-Sky	Broadband	68 nm	65 nm	95%
Parks LPR	Broadband	50 nm	41 nm	90%
Celestron LPR Type A	Broadband	47 nm	30 nm	92%
Daystar 300	Broadband	35 nm	31 nm	95%
Meade #908	Broadband	35 nm	19 nm	83%
Lumicon UHC	Narrowband	27 nm	25 nm	96%
Orion UltraBlock	Narrowband	24 nm	20 nm	85%
Lumicon OIII	Line	11 nm	9 nm	98%
Lumicon H-Beta	Line	10 nm	8 nm	96%

Filters listed in order of decreasing bandwidth.

of each major class of deep-sky objects.

Galaxies: Using the 12.5-inch Newtonian at our dark site, we looked at two galaxies, M64, the Blackeye Galaxy, and M82. While all the filters we tested darkened the sky background and produced a more aesthetically pleasing view, there was no visible improvement in the way the galaxies actually looked. That is to say, no further details were visible with the filters in place. Only higher magnification could bring out details like faint spiral arms, superimposed field stars, and dark patches.

Under city skies, we looked at M51, the Whirlpool Galaxy, and M82 with an 8-inch SCT. Again, we could see no further detail with any of the filters in place. The SkyGlow and Deep-Sky filters provided the most "natural" view, while the Daystar 300, the Celestron, and the Meade cut out the background sky and the galaxy to a greater extent. The Parks filter was intermediate in effect.

From these results you may conclude that galaxies are a poor target for nebula filters. In most cases this is true. However, we have noted that some galaxies, especially those near the threshold of visibility, can be enhanced to a certain extent. M33 is an example of a low surface brightness galaxy that can respond well to filters. In some cases, we found a broadband filter made the difference between detecting an object and not seeing it at all.

Star Clusters: In all cases, we found that open and globular star clusters were best seen without a filter. This was true no matter what the site, telescope, or filter. As might be expected from our observations of galaxies, the broadband filters provided a nicer sky background, but did little to increase detail. In fact, fewer stars were visible with a filter in place. Even the mildest of filters chopped off enough light so that faint stars were lost. There was also a slight decrease in sharpness with all of the filters — this made clusters look "mushy."

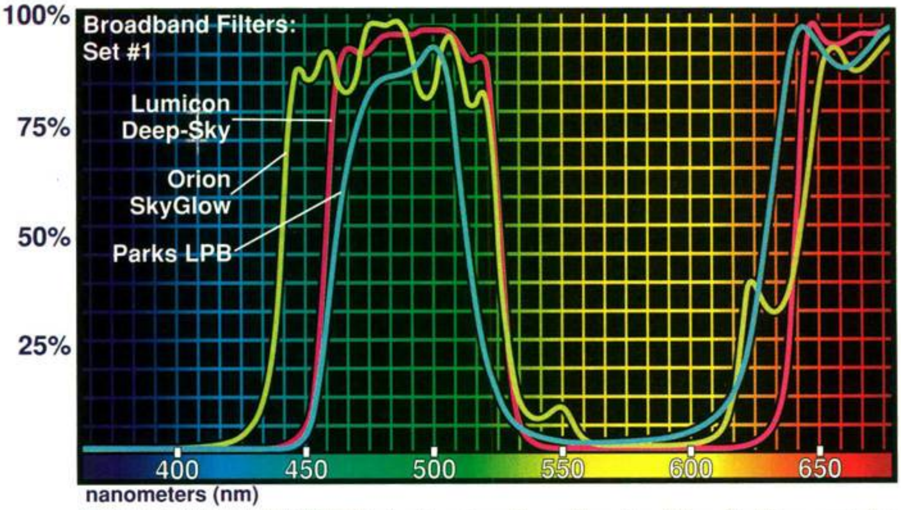
Reflection Nebulae: The blue component of the Trifid Nebula (M20) was the best example of a reflection nebula available to us when we did the tests. Flipping around the filter wheel was an eye-opening experience with the 12.5-inch scope at our dark site. The change from one filter to the next was obvious. Lumicon's premium Deep-Sky filter clearly had the best contrast. The apparent size of the nebula swelled by a factor of two or more, and internal mottling became evident. The Parks filter was a close second. Internal details were still visible. The Celestron, Meade, and Daystar filters didn't perform as well — they increased the size of the nebula only a little. Of this trio, the Celestron was marginally better than the Meade and Daystar. Among the six broadband filters, Orion's SkyGlow was a distant last place. But by darkening the sky slightly it still beat the unfiltered natural view. All things considered, we were impressed by the enhancement of the Trifid Nebula's blue component by the Lumicon and Parks filters. However, from within the city, none of the filters could cut through the overpowering light pollution to bring out this object.

Emission Nebulae: Summer's most impressive emission nebula is arguably M8, the Lagoon Nebula. M8 has a bright core, called the "Hourglass," with a second, fainter feature off to the southeast, and a much fainter and larger swath to the north. From country skies with the 12.5-inch , the Meade and Daystar gave the best views — M8 was significantly larger and more detailed. Slightly behind the tied winners was the Celestron — it did not enhance the faint patch to the north quite as much. The Parks and Deep-Sky showed somewhat less, while the SkyGlow was least effective. In the city with the 8-inch SCT and refractor, the results were the same, except that we couldn't see any difference between the Celestron, Daystar, and Meade filters. From the country, the Meade and Daystar also performed best on the Dumbbell Nebula (M27), bringing out the faint "wings" of this planetary nebula.

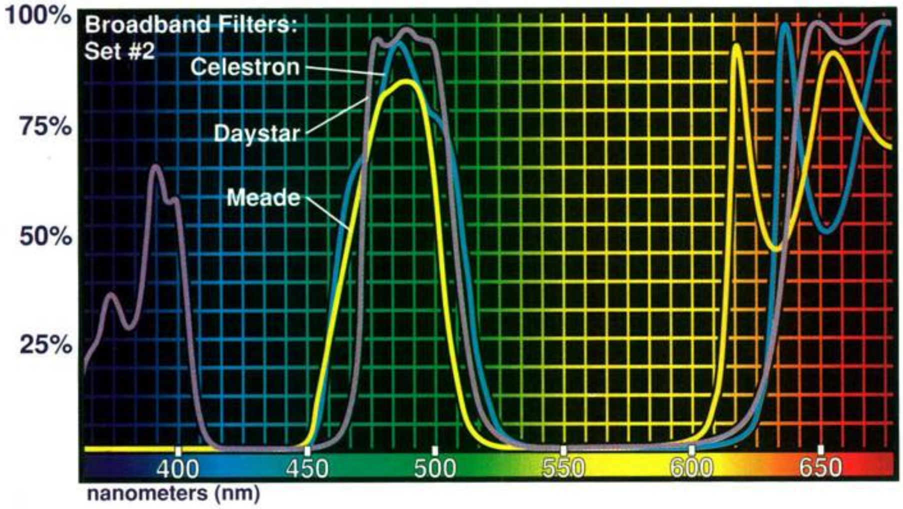
The Narrowband Filters

We categorized two filters as "narrowband": the Lumicon premium UHC (Ultra-High Contrast) and the Orion UltraBlock. Both are advertised as being suited for severe cases of light pollution or for faint nebulae. We tested these filters primarily on emission and planetary nebulae. Their extreme rejection of the majority of the visible spectrum makes these filters unsuitable for continuous-spectrum objects like galaxies and clusters. When used on the blue reflection nebulosity of the Trifid, the narrowband filters, as expected from their design, performed very poorly.

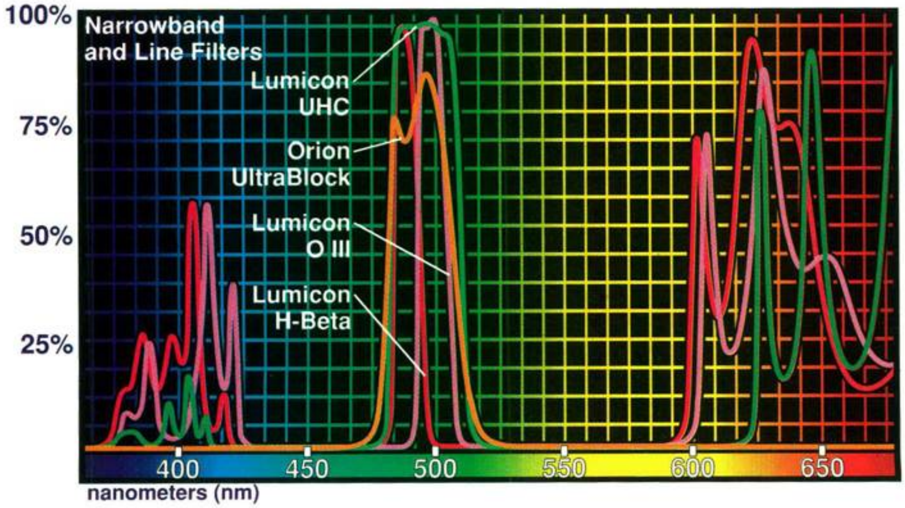
However, from our city location with the SCT and refractor, the UHC and UltraBlock improved the Lagoon Nebula dramatically. The fainter swath on the north side of the Lagoon was significantly easier to see with these two filters than with any of the broadband models. We had to flip back and forth between the two narrowbands a few times before convincing ourselves that the UltraBlock was slightly better. This result certainly surprised us, since the UHC filter is more expensive and has become the filter of choice among many observers. We checked this result on the Veil Nebula from the country using the 12.5-inch. Again, the UltraBlock gave superior results. Our target was the faint triangular section between the two main arcs of this supernova remnant. On this threshold object we could definitely see more nebulosity and greater detail with the UltraBlock filter than with the UHC.



THREE "NATURAL" FILTERS: the Lumicon Deep-Sky, the Orion SkyGlow, and the Parks LPB. Their wide bandwidths made them suitable for enhancing many kinds of deep-sky objects. With a bandwidth we considered too wide, the Orion SkyGlow showed the least contrast enhancement.



THREE SIMILAR FILTERS: the Celestron LPR Type A, the Daystar 300, and the Meade #908. Their performance was similar on most objects, with the narrower bandwidth of the Daystar and Meade giving them a slight edge over the Celestron on emission nebulae. The Daystar and Meade also have good red H-alpha transmission for photography.



FOUR HIGH-CONTRAST FILTERS: the Lumicon UHC, OIII, H-Beta, and the Orion UltraBlock. The UltraBlock and UHC both encompass the all-important OIII and H-beta lines emitted by nebulae. The UltraBlock showed slightly higher contrast than the UHC due to its narrower bandwidth. The OIII and H-Beta filters single out only those lines.

The Line Filters

Only two filters that we tested fell into this category: the Lumicon Oxygen III and H-Beta filters. As with the narrowband models, the line filters are only useful for emission objects. We did not test them on galaxies, reflection nebulae, or clusters.

The Oxygen III Filter: This remarkable filter is in a class by itself. Inserting an OIII into the light path on an emission nebula is like doubling the size of your scope! We found both the Lagoon and Swan Nebulae to be stunning sights, both from the city and country sites. Under a dark sky, the views resembled long exposure photographs. Even the narrowband filters didn't approach the striking contrast achieved by the OIII. With this filter, the Lagoon apparently doubled its size and showed such a wealth of detail that we would have been hard pressed to make an accurate drawing.

From our dark site, the Veil and the Crescent Nebulae (NGC 6888) stood out in sharp relief against the sky. The wisps and patches in the broad eastern section of the Veil, for example, were transformed into a detailed lacework of braided filaments. From past experience we've also found that with an OIII filter faint planetary nebulae pop into view with ease.

Since even the darkest country skies are brightened by airglow, an OIII filter has become a standard item for us at all observing sessions. It suppresses most sky glow to let the nebulae blaze through.

What's the drawback? An OIII filter kills stars by two to three magnitudes. The sky can get so black at medium and high powers that it can be difficult finding the field. We've found that an OIII works best at low magnifications, say 3 to 5 power per inch of aperture (exit pupils of 5 to 7mm).

The H-Beta Filter: The H-Beta has been nicknamed "the Horsehead"or "the California" nebula filter. Even from our site 25 miles north of Toronto, we regularly observe the elusive Horsehead Nebula with an H-Beta and a 12.5-inch scope. This challenging object is invisible with other filters even on our best nights. However, other than the Horsehead and the California Nebulae, we've discovered few objects where an H-Beta works better than an OIII filter.

We have found that an H-Beta can be useful for highlighting different structures within a nebula. M42, the Orion Nebula, is an excellent example. Even though it is brighter with an OIII filter, M42 displays new structure when viewed in the light of H-beta emission.

RATING THE FILTERS

Broadband Filters	Galaxies	Clusters	Reflection Nebulae	Emission Nebulae
Orion SkyGlow	3	2	1	1
Lumicon Deep-Sky	3	2	4	2
Parks	2	2	3	3
Celestron	2	1	2	4
Daystar	2	1	2	5
Meade	2	1	2	5
Narrowband Filters				
Lumicon UHC	n/a	n/a	n/a	7
Orion UltraBlock	n/a	n/a	n/a	8
Line Filters				
Lumicon OIII	n/a	n/a	n/a	10
Lumicon H-Beta	n/a	n/a	n/a	10 *

* The H-Beta works well on only a few objects. See text.

Filters are rated from 1 to 10 for each type of object, with 1 = little enhancement and 10 = maximum enhancement and contrast gain.

The Lab Tests

From our tests at the eyepiece we had a firm ranking of the filters for each application. We were anxious to see if the lab tests confirmed our impressions. We were pleased to see they did. The spectral curves shown on page 78 explained why we saw what we did at the eyepiece.

For example, the filters that gave the best results on reflection nebulae (Lumicon Deep-Sky and Parks LPB) have more bandpass towards the blue. However, the Orion SkyGlow has too much blue transmission. It lets through too much unwanted light, hence its ranking near the bottom in most situations. The Lumicon Deep-Sky, being slightly narrower in its bandpass than the SkyGlow, provided better contrast while still transmitting enough visible light to make it useful on reflection nebulae and other continuous-spectrum objects.

The SkyGlow's transmission curve extended to 440 nm at the 50-percent level, bringing it very close to the mercury-vapor line at 435.8 nm. By comparison the Lumicon Deep-Sky exhibited a blue cutoff point of 457 nm at the 50-percent level. Interestingly, Lumicon advertises the Deep-Sky as having a cutoff at 441 nm, similar to the SkyGlow. The fact that it fell short of this worked to its favor.

Compared to the SkyGlow and Deep-Sky, the Parks LPB has a bandpass that is slightly narrower still, but is wider than either the Celestron, Meade, or Daystar. This explains the relative ranking of these units on reflection and emission nebulae. (The narrower the bandpass, the better for emission objects, but the worse for reflection nebulae and continuous-spectrum sources.)

The lab tests also showed why the UltraBlock gave consistently higher contrast than the premium UHC. At first glance, the UHC has a textbook design, with a transmission level some 10 percent higher than the UltraBlock's. Why, then, is the UltraBlock's contrast higher? Because its bandwidth is 4 nanometers narrower (at a level between 60 to 70 percent transmission). Since the UHC is passing unwanted light through this gap, and at a very high efficiency, we can only conclude that is why its contrast is lower despite the seemingly higher quality specs. This has interesting repercussions for the industry. We have seen here that a filter with lower transmission but narrower bandpass gives an overall higher contrast. Perhaps manufacturers should adopt a uniform method of stating transmission percentages and bandwidths.

The filters exhibited considerable variation in the red end of the spectrum. Since the dark-adapted eye is largely insensitive to red, for visual use this red-end variation makes little difference. However, for photography (either color or black-and-white) good transmission of the hydrogen-alpha line at 656.3 nm is critical. The Daystar, Lumicon Deep-Sky, Meade, Parks LPB, and Orion SkyGlow all showed good H-alpha transmission. In addition, the Daystar's unique transmission of blue wavelengths between 360 nm and 400 nm includes the calcium H and K lines. While our interest in this review was in the visual performance, we suspect that an appropriately mounted Daystar might make a good photographic filter.

So Which is Best?

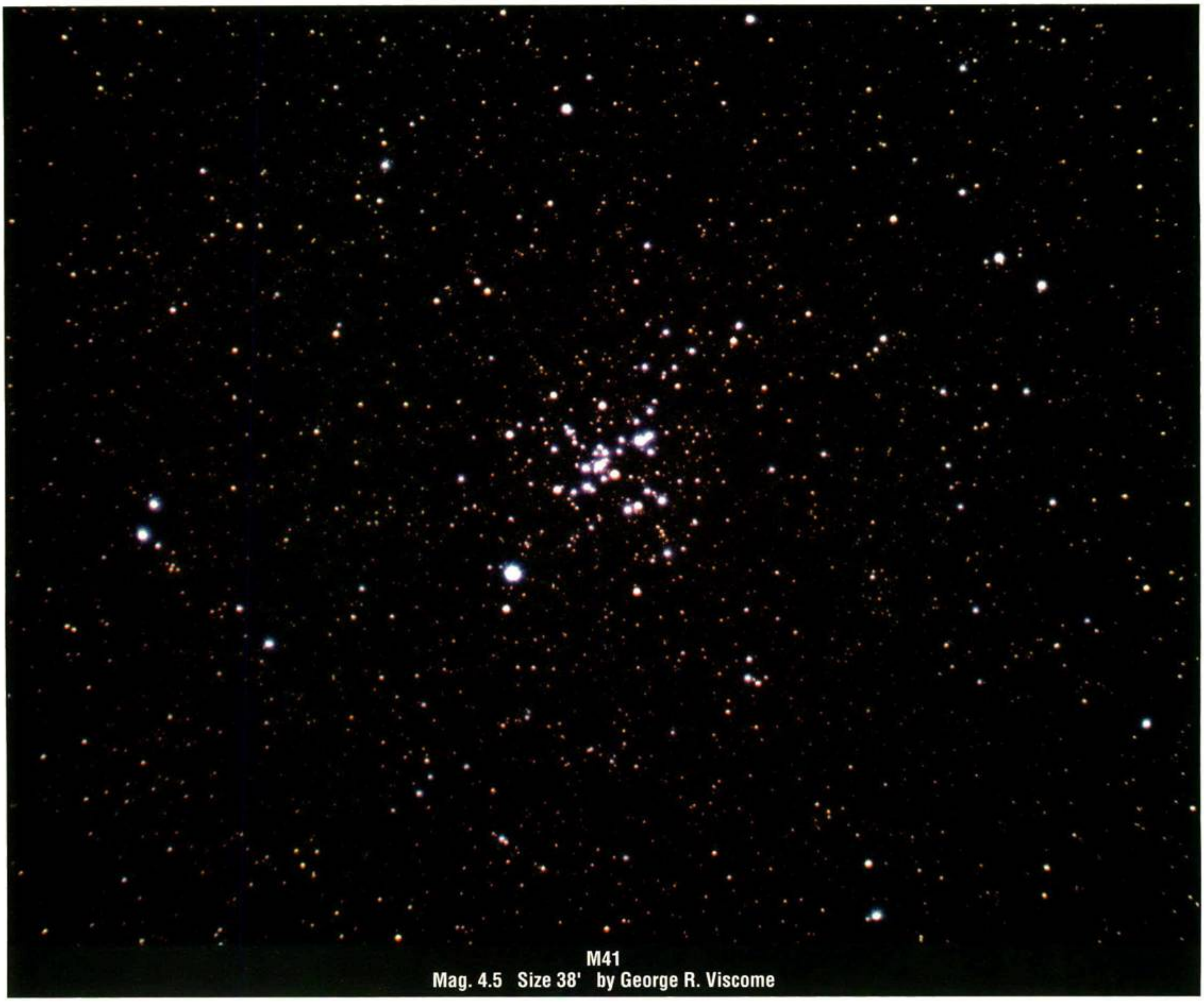
The best filter depends on your observing interest, site, and budget. The Celestron, Daystar, and Meade filters strike a reasonable balance between bandwidth and versatility, performing equally well on most types of objects at both urban and dark sites. In the lab, the Meade exhibited a lower maximum transmission than either the Celestron or Daystar but this difference wasn't noticeable at the eyepiece. However, none of these three general-purpose filters excelled in any one category.

The Lumicon Deep-Sky and Parks filters are good for use at suburban sites on reflection nebulae and some galaxies. Both the UltraBlock and the UHC work best on emission sources and work well at any site. Compared to an OIII filter, these two filters are more suited to higher powers (10 to 20 power per inch of aperture). At $20 less than the UHC and with slightly superior performance, the Orion UltraBlock is a good value. However, on the majority of emission nebulae especially when used at low power, the Lumicon OIII proved to be our favorite. We recommend this filter for any sky condition or telescope since it gives the greatest contrast gain.

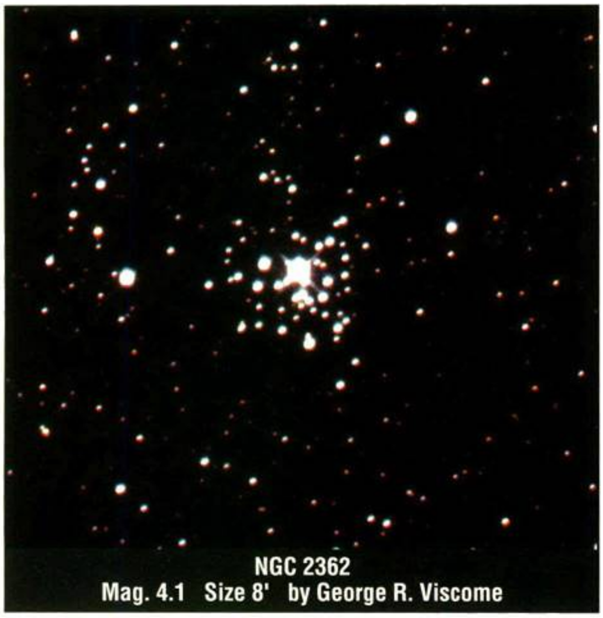
The H-Beta filter also works wonders but only on a handful of nebulae. For most people we can't recommend an H-Beta as essential equipment. It is a specialty item for the nebula fanatic.

Which filter should you buy? If you dabble in all kinds of deep-sky observing, we'd suggest either the Celestron, Daystar, or Meade. If deep-sky observing is your all-consuming passion, a better choice is to buy two complementary filters. Based on our tests, we'd recommend a Lumicon Deep-Sky and an OIII. In either case, you'll soon find that a nebula filter will become one of your most-used accessories. □

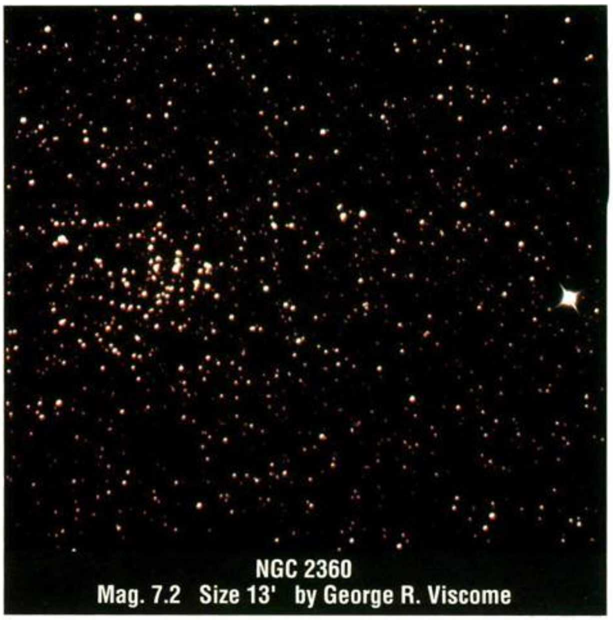
Alister Ling and Jerry Spevak have between them 27 years experience as deep-sky observers. Alister Ling's last article for ASTRONOMY *was "Ten Tips for Improving Your Telescope" in August 1990. The authors wish to thank Bob Simpson of the National Research Council of Canada for assisting with the lab tests.*



M41
Mag. 4.5 Size 38' by George R. Viscome



NGC 2362
Mag. 4.1 Size 8' by George R. Viscome



NGC 2360
Mag. 7.2 Size 13' by George R. Viscome

Exploring Open Clusters in Canis Major

Filled with sparkling star groups, Canis Major is a powerful attraction on chilly winter nights.

Phil Harrington

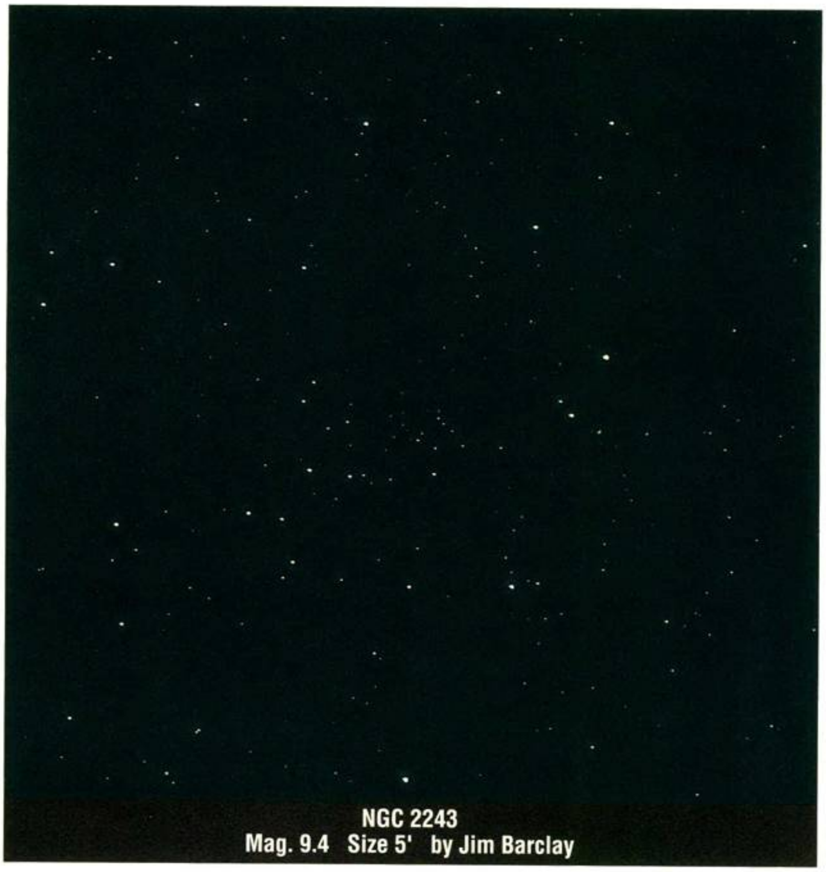
Stretching from horizon to horizon and passing through the zenith, the Winter Milky Way is a glorious haven for deep-sky observers. As you scan along the hazy glow of our Galaxy, you'll occasionally see islands of stars — open clusters. These groups of young stars formed from clouds of interstellar gas and dust, and will ultimately break apart as they revolve about the center of the Galaxy. Some of the finest examples of open clusters on the edge of the Milky Way are within the constellation of Canis Major, the Large Dog.

Canis Major is easily found southeast of Orion thanks to the presence of its brightest star, **Sirius** (Alpha Canis Majoris). At magnitude –1.4, Sirius is the brightest star in the sky. It shines like a brilliant blue-white diamond suspended against a velvety black field of stardust. Nearly 4° south of Sirius is the pre-eminent open cluster in Canis Major — **M41** (NGC 2287). M41 is bright enough to be visible to the naked eye on dark nights and was mentioned as a curious "cloudy spot" by Aristotle, who noted it in the year 325 B.C. From a dark, rural site, you can easily duplicate Aristotle's observation and use the naked-eye visibility of M41 to gauge the sky's transparency.

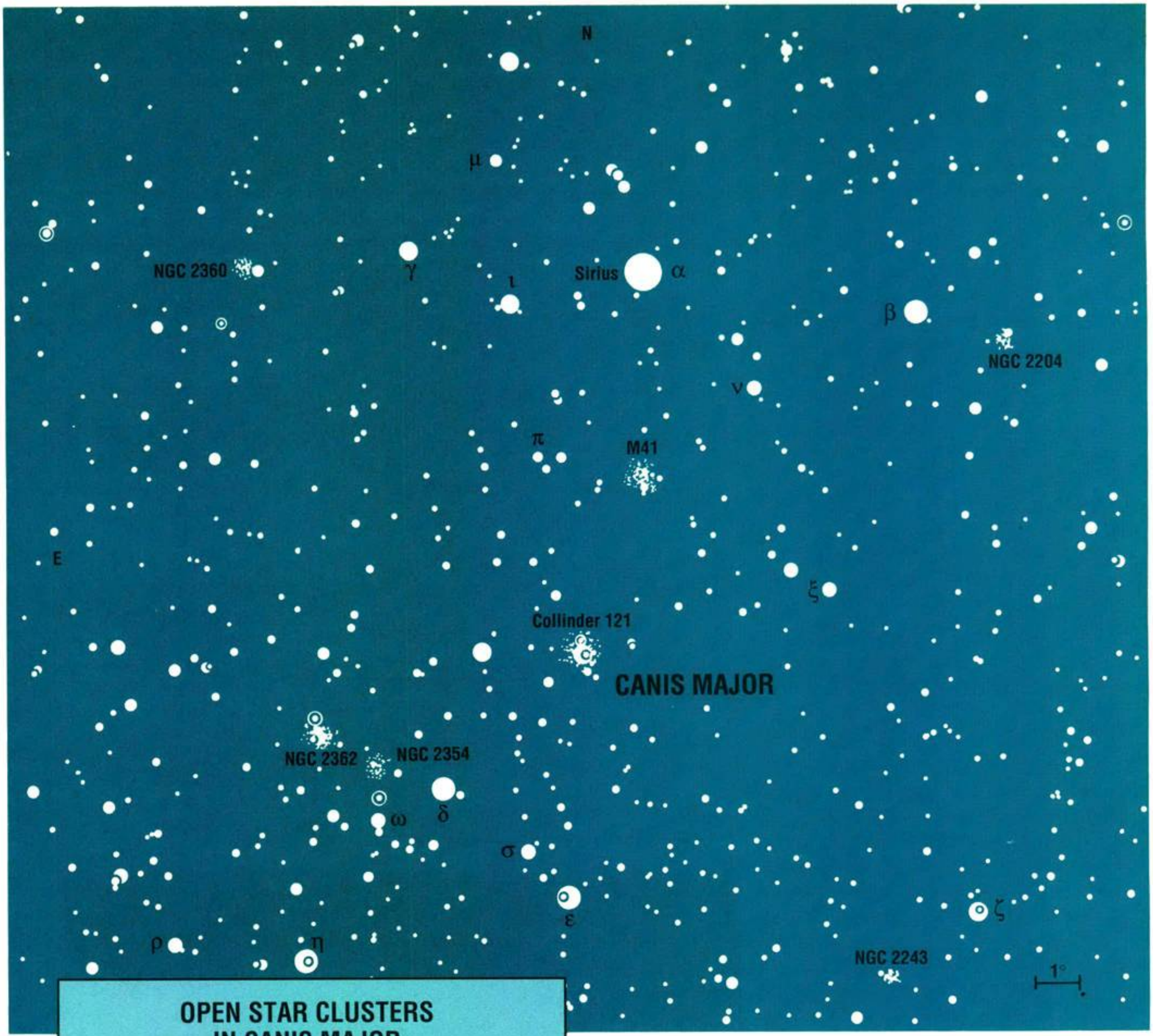
Today we know that M41 consists of about 80 stars, most of which glow in subtle hues of yellow, white, or blue-white. M41's brightest star is slightly brighter than 7th magnitude; 20 of its stars are brighter than 10th magnitude and are therefore visible in large binoculars and finderscopes. A 3- to 4-inch telescope resolves about half of the stars in M41, while an 8-inch instrument shows the cluster in all its glory. Most observers immediately notice that four of M41's brightest stars form a trapezoidal figure that bears a strong resemblance to the "keystone" asterism in Hercules. M41's other stars appear to form lines and curving arcs that extend away from the central trapezoid.

From edge to edge, M41 spans 38' — larger than the disk of the Full Moon. Because of this, low-power, wide-field eyepieces are best for taking in all of the cluster. High magnifications fail to provide a satisfying view of the entire group.

The 2nd-magnitude star Wesen (Delta Canis Majoris) marks a convenient starting point for finding a pair of open clusters. Just 1.5° northeast of Wesen, well within the same finderscope field, is **NGC 2354**. This cluster is composed of one hundred 9th-magnitude and fainter stars contained within 20'. Through binoculars, NGC 2354 appears as a faint mist nestled in a rich surrounding field. A 4-inch telescope resolves the cluster's brightest stars. With an instrument twice that size,



NGC 2243
Mag. 9.4 Size 5' by Jim Barclay



OPEN STAR CLUSTERS IN CANIS MAJOR

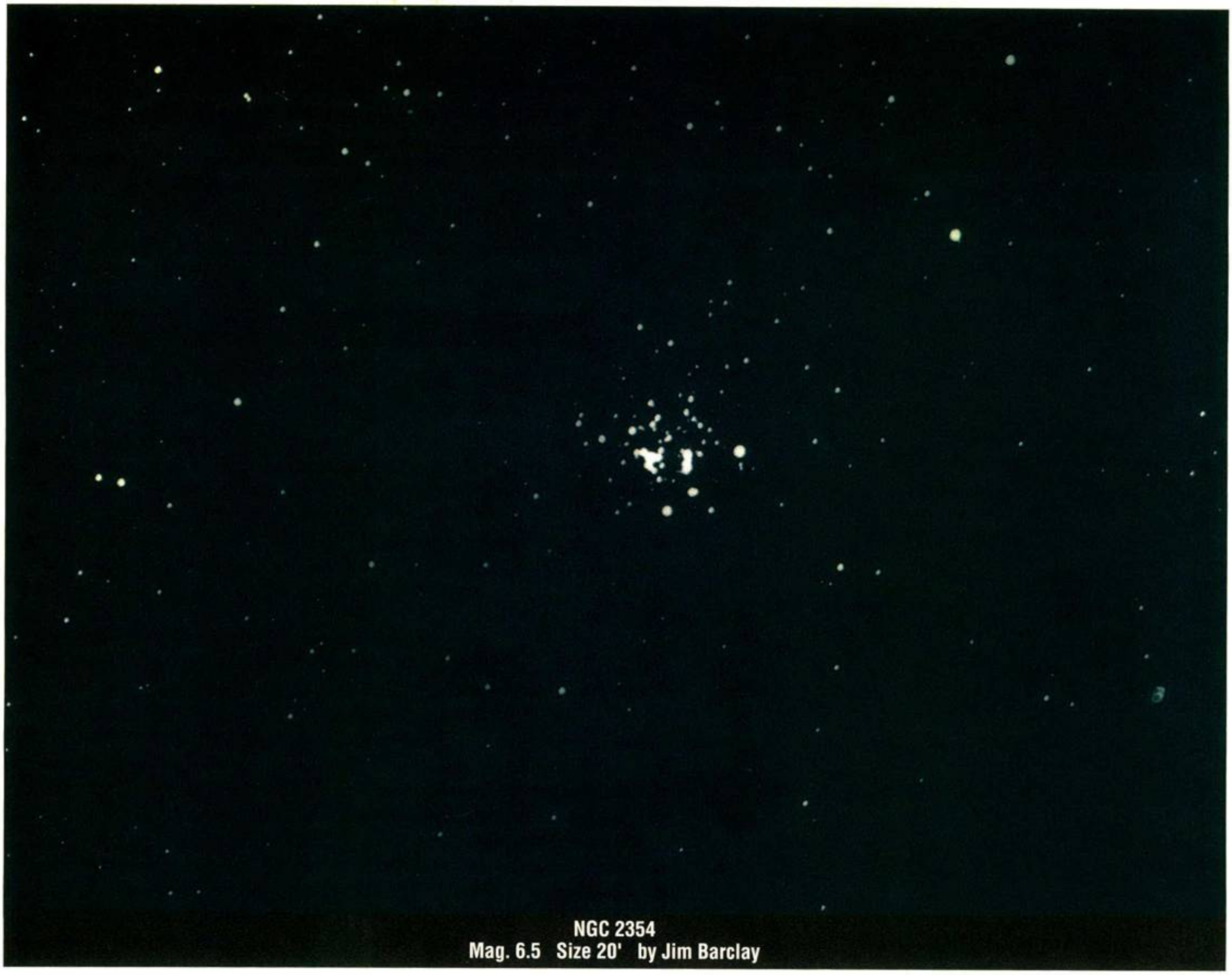
Object	R.A. (2000.0)	Dec.	Mag.	Size
NGC 2204	6h15.7m	-18°39'	8.6	13'
NGC 2243	6h29.8m	-31°17'	9.4	5'
M41 (NGC 2287)	6h47.0m	-20°44'	4.5	38'
Cr 121	6h54.2m	-24°38'	2.6	50'
NGC 2354	7h14.3m	-25°44'	6.5	20'
NGC 2360	7h17.8m	-15°37'	7.2	13'
NGC 2362	7h18.8m	-24°57'	4.1	8'

Object: Designation in Messier, NGC, or Collinder catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude of cluster. **Size:** Diameter in arcminutes.

you'll see more than twice as many stars, with many of the brighter cluster members taking on a soft, yellowish hue. Once again, your widest-field eyepiece will yield the most pleasing views.

That rule does not hold true for our next object, however. Located 1° northeast of NGC 2354, **NGC 2362** consists of 60 stars crammed into 8'. Though small, NGC 2362 is a snap to spot since it surrounds the 4th-magnitude star Tau Canis Majoris. Large binoculars and small telescopes reveal a few 7th-magnitude cluster stars, along with Tau, embedded in the haze of fainter, unresolved stars. Eight- to 10-inch scopes display nearly all of the cluster's stars.

To find the next cluster, begin at 2nd-magnitude Murzam (Beta Canis Majoris), some 5° west-southwest of Sirius. From Murzam, move another 1.5° to the west-southwest, where your finder will uncover a single 6th-magnitude star and a faint glow nearby. The faint glow is the collective effect of the 80 stars belonging to **NGC 2204**. This cluster is less impressive than M41 or NGC 2362, but it is pretty enough to make the hunt worthwhile. You'll do best by switching to a moderate-power eyepiece first, because the cluster stars — none of which are brighter than 12th magnitude — all but hide in the rich background stars at low magnifications. The main body of the cluster measures 6' by 4', and outlying members extend this to 13'.



NGC 2354
Mag. 6.5 Size 20' by Jim Barclay

Easier to spot is **NGC 2360**, located about 8° east of Sirius and just east of a 7th-magnitude field star. Here you'll find a compact group of 80 stars that to many observers appears like an arrowhead. This shape is even discernible in large binoculars, although most of the stars are too faint to be seen individually. A good 4- to 6-inch telescope, however, cleanly resolves NGC 2360, showing many yellow and blue-white stars scattered across the cluster's 13' span.

Without a good view to the south, most observers tend to shy away from our next open cluster. **NGC 2243** lies in the constellation's southwestern corner and culminates less than 20° above the horizon for much of the United States, Canada, and Europe. Add to this its isolation from any bright stars, and it's easy to see why NGC 2243 is known to so few amateurs.

Actually, NGC 2243 is easier to find than it might appear at first. Begin your hunt at Adhara (Epsilon Canis Majoris) and cruise 7.5° southwest of 4th-magnitude Lambda Canis Majoris. NGC 2243 lies adjacent to a 6th-magnitude star, less than 2° to Lambda's north-northeast. Once in the region, your finderscope should reveal its small, subtle glow.

NGC 2243 is an exceedingly rich open cluster, in the same league as M11 in Scutum. The limited resolving power of small scopes causes it to look more like a globular cluster. An 8-inch instrument reveals only ten individual stars set within the group's hazy glow, while my 13.1-inch f/4.5 Newtonian doubles the star count. Because of its compactness, NGC 2243 can handle magnification well, so don't be afraid to crank it up!

Our last cluster belongs to the Collinder catalog of open clusters. This family of clusters is best known for large size and bright stars. **Collinder 121** spans 50' and shines at magnitude 2.6. Omicron^1 Canis Majoris, lying on the cluster's northern edge, shines at 4th magnitude and contributes much to the group's overall brightness. The other 20 or so stars in the cluster are not as bright — two shine at 6th magnitude and the rest between magnitudes 8 and 10. Combined with the starriness of the surroundings, the stars' magnitudes make it difficult to tell exactly where Collinder 121 begins and ends.

We've merely sampled the many fine open clusters scattered across Canis Major. With such a wide variety of sights from which to choose, don't let the cold get to you — conquer the beauty of Canis Major! ☐

Phil Harrington is an avid observer who lives in Smithtown, New York. His last article was "Scanning the Scutum Starcloud," in the July 1990 issue.

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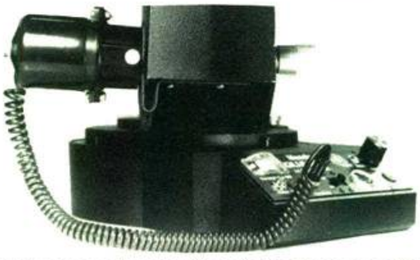

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2040	1,2,3,4,7
2045	1,2,3,4,6,7
2045D	1,2,3,4,6
2080/2120 GEM	1,2,3,4,5,6,8
6600/8800	5,6,8
295/310/320	5,6,8
628/645/826/856	1,2,3,4,5,7
880/1060/1266	1,2,3,4,5,7
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C-5	5,7
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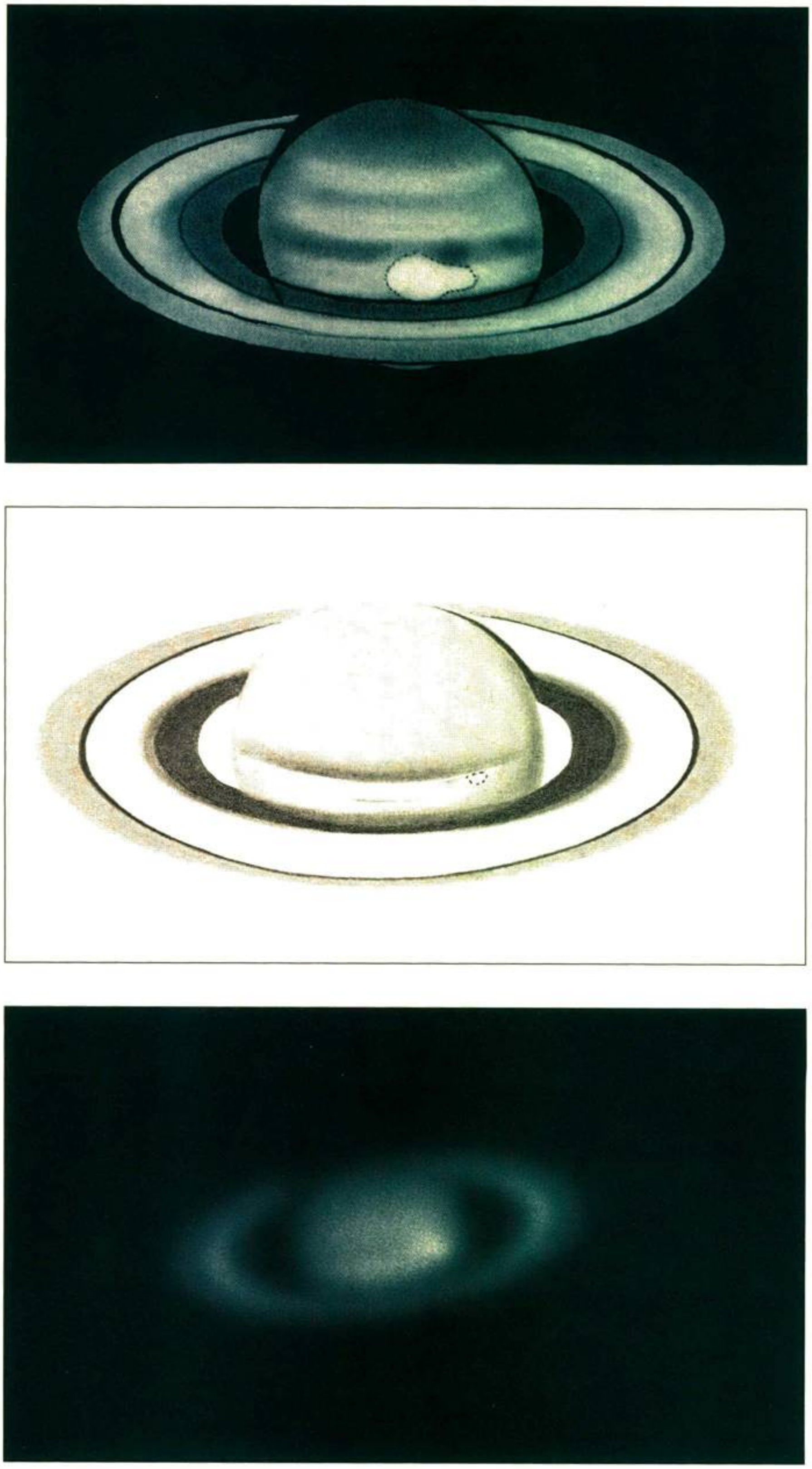
SATURN'S LARGE WHITE SPOT

On September 25, 1990, observers in Las Cruces, New Mexico, noticed an anomalously bright area on Saturn as they observed the planet with small telescopes. The ringed planet has a history of producing small white spots from time to time, but the New Mexican observers were surprised by this spot's large size. Three nights later a group led by Las Cruces comet hunter Alan Hale and including Clyde Tombaugh, the discoverer of Pluto, watched the great white spot as it slowly rotated across Saturn's globe.

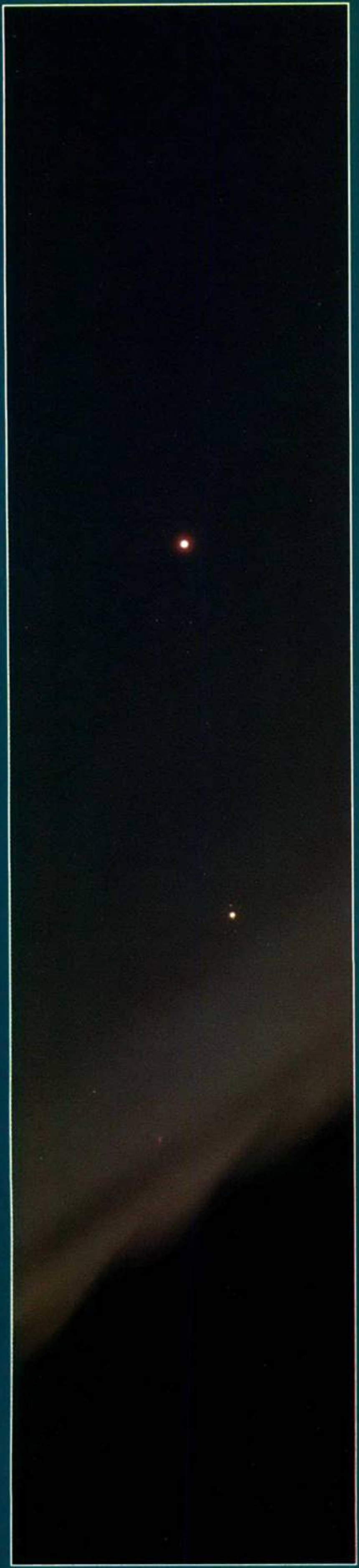
By October 1 hundreds of backyard skywatchers had viewed the spot. On that evening Lawrence K. Hubble of Havre de Grace, Maryland, captured the spot photographically using fine-grain Tech Pan film. "The photo was taken only six days after the spot's discovery," relates Hubble. "It clearly shows a light-colored area on Saturn's disk that is larger than the Red Spot on Jupiter."

The following night French observer Jean Dragesco used his 14-inch f/10 SCT to sketch the planet and its spot from St. Clement, France. Despite "very bad seeing," Dragesco remarks that "the white spot on Saturn's equatorial region seems to be the most brilliant I have ever seen. It was a splendid view."

In Tucson, Michael Sweetman observed and sketched Saturn on several occasions during the first days of October. "I received a phone call from Rik Hill, solar recorder for the Association of Lunar and Planetary Observers," says Sweetman. "Hill alerted me to the presence of a very large white spot on Saturn. I was particularly interested because I have been following Saturn throughout the current apparition, and observed a bright area in the planet's equatorial zone on July 25. The current bright spot, however, is far larger and brighter. I can't imagine anyone looking at Saturn at the time with any



A LARGE WHITE SPOT was discovered on Saturn's disk on September 25, 1990; it remained visible in small telescopes for several weeks. On October 2 French observer Jean Dragesco sketched the spot using a 14-inch SCT at 224x (top). Five nights later Michael Sweetman of Tucson sketched the spot, which then appeared more like a band (center). Sweetman used a 6-inch f/10 refractor. On October 1 Lawrence K. Hubble of Havre de Grace, Maryland, photographed the spot with his astronomy club's 16-inch Cassegrain at f/70 (bottom).



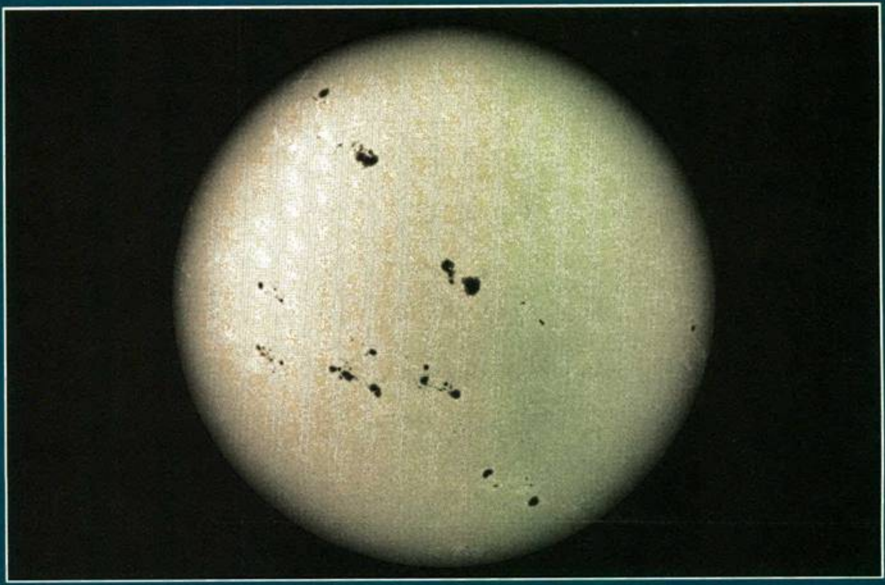
FIRE ON THE SUN

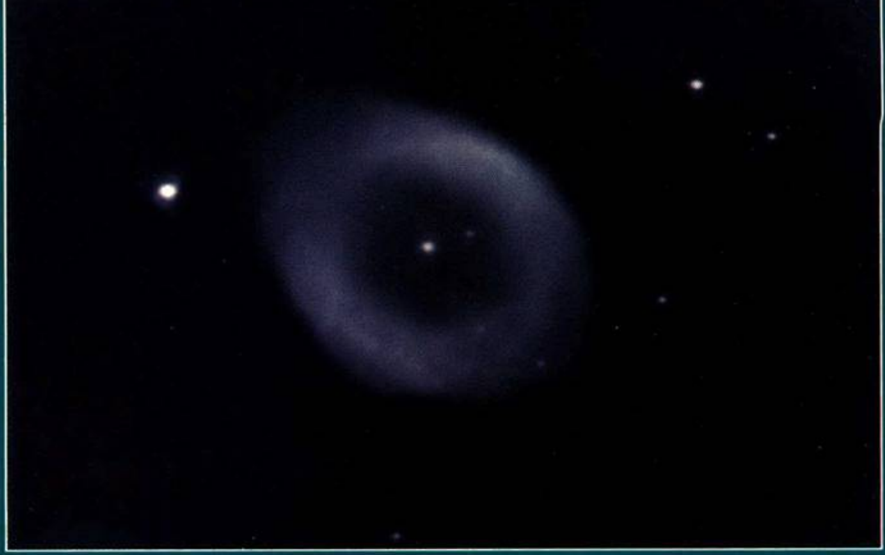
Last autumn the French astrophotographer Gerard Therin captured a spectacular solar flare, which nets this month's $100 "Best Astrophoto" award (opposite page). Therin used a 4-inch f/15 refractor, Tech Pan film, and a 1/125-second exposure with a 20A hydrogen-alpha filter.

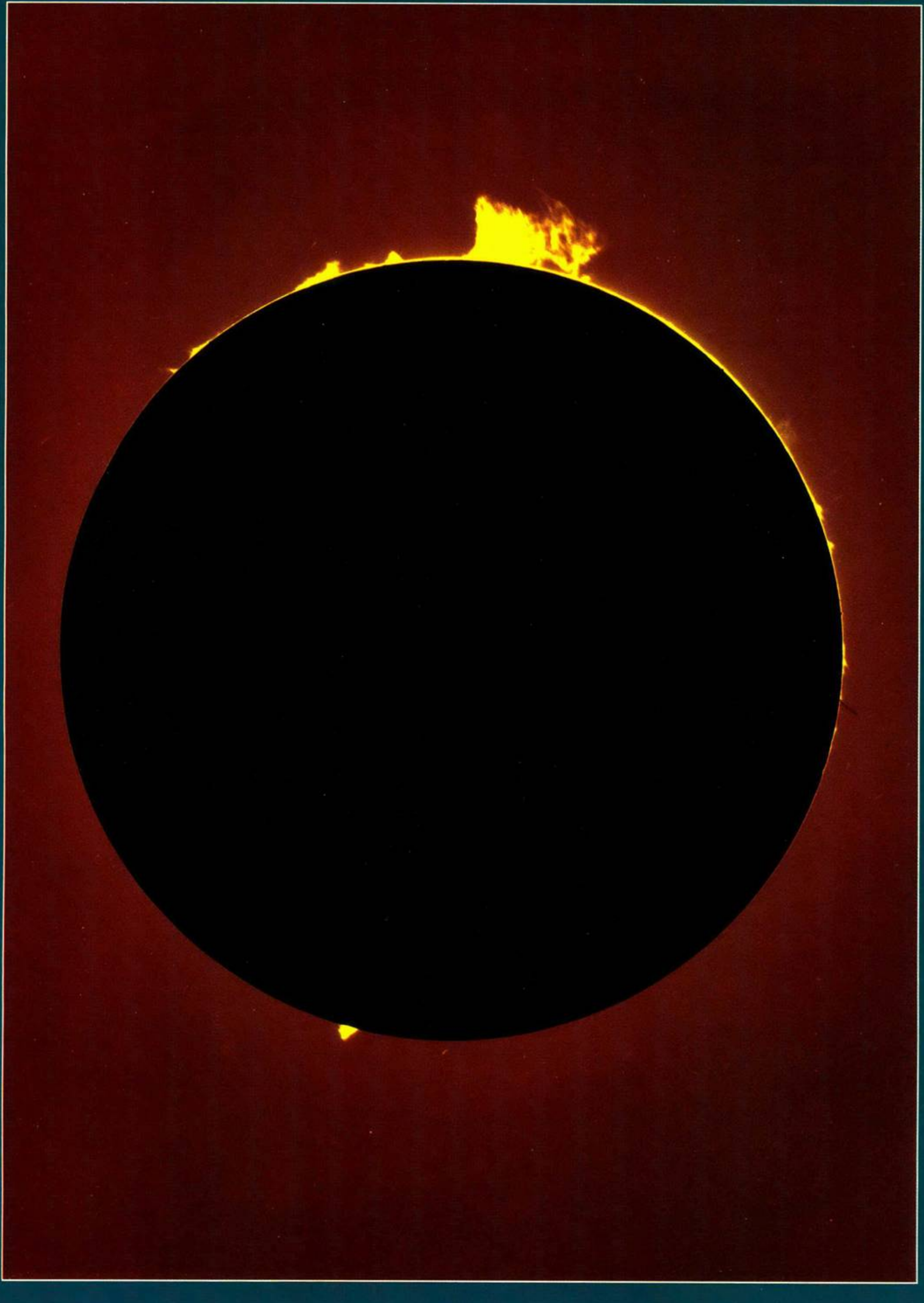
On July 2 another Frenchman captured a stunning solar portrait. Jean Dragesco's photo, made with both a solar filter and a Wratten #58 filter, shows a solar disk splattered with sunspots (below). Dragesco used a 7-inch Starfire refractor at f/13, Tech Pan film, and a 1/2000-second exposure.

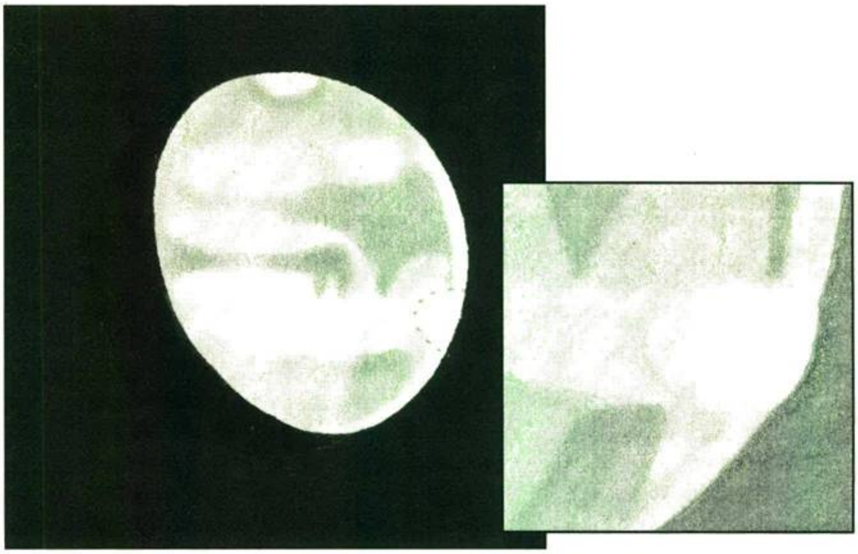
Venus and Jupiter beamed in the early morning sky on August 10, when Californian Ronald E. Royer captured them on film (left). Royer used a 4-inch f/5 astrograph, Ektachrome 200 film, and a 1-minute exposure.

University of Arizona astronomer J. Davy Kirkpatrick and his students at an astronomy camp last summer had the incredible opportunity to photograph deep-sky objects with the University's 90-inch telescope on Kitt Peak. Kirkpatrick and his students captured an impressive "amateur" photo of the Ring Nebula in Lyra (bottom).









DUSKY MARTIAN MARKINGS stand out in this drawing made by English observer Matthew Boulton on August 26, 1990. Boulton used a 6-inch reflector and yellow and blue filters to capture details such as Saebeus Sinus, Ganges, Argyre I, and a large white cloud above the planet's morning limb. The inset shows the cloud in greater detail.

telescope and not seeing it, if the spot was on the part of the planet facing us."

On October 2 professional astronomers at the Instituto de Astrofisica de Canarias at Santa Cruz, Tenerife, timed the spot's rotation and calculated its size as 20,000 ± 1,000 kilometers.

PLANET WATCHING IN BRITAIN

"I am one of many ASTRONOMY readers in England who applaud the magazine's efforts with 'Reader Reports,' and therefore have sent a package of sketches we hope you will enjoy," says Paul A. Smith of Darlington, England. "Several of us regularly sketch planets and keep in touch by correspondence, chiefly fellow Jupiter freak Matthew Boulton of Redditch, England, and our Australian planetary observer friend Paul Brand," remarks Smith. "Although what we have sent you fits in a small envelope, it represents many hours of hard work."

Smith and Boulton's series of sketches were made with 6-inch scopes at medium and high magnifications, and show a wealth of detail that testifies to their observational skills. They have enjoyed following the disappearance and reappearance of Jupiter's South Equatorial Belt — "and they say Earth's weather is unpredictable," they declare — and have made a fine series of drawings documenting details on the Martian globe during the current apparition. We plan to share more of Smith and Boulton's work with readers in the future. — *David J. Eicher.* □

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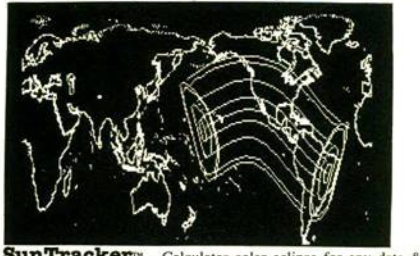

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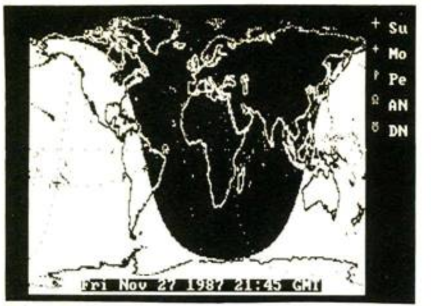

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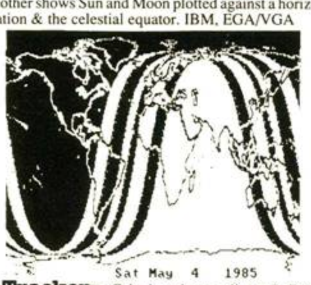

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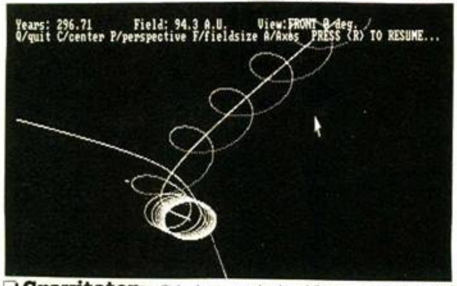

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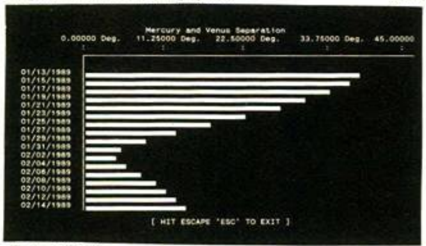

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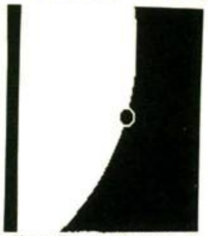
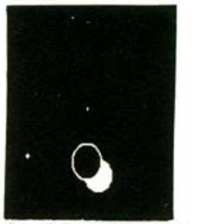


Venus Transit, 7/11/5900 AD



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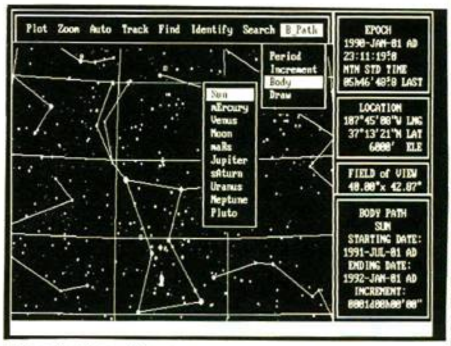

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37°13'21"N LAT
6000'  ELE

FIELD of VIEW
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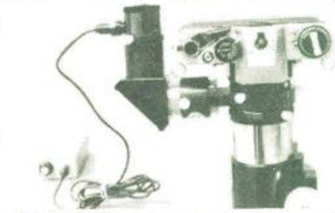

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Adapter for Pentax 6X7 medium format **$89**
3X Relay Diagonal **$89.50**
12mm illum. reticle eyepiece system, wireless **$99.50**
48mm DEEP-SKY Filter ($119.50) . . . . . add **$99.95**

QUARTZ DRIVE CORRECTOR

New Lumicon Dual-Axis Drive Corrector
Allows fine corrections in right ascension and declination for astrophotography. Compact control allows "one-hand" operation. Also permits field use of your telescope off a 12V car battery. 60.00 Hz Quartz reference; 40/80 Hz variable output controls telescope drive; ± 12VDC Declination control output; Declination polarity reversing switch for equatorial mounts; both 12VDC & 110 VAC input for home or field use.

Lumicon Quartz Drive Corrector . . **$219**
Declination Motor (specify telescope) **$99**

NEW DIGITAL DRIVE

- Quartz crystal digital frequency generation
- Switchable lunar, solar, sidereal rates
- Normal or fast (0,120Hz) R.A. corrections
- Illum. reticle output w/brightness control
- Map, R.A., dec. setting circle illuminator output jack with brightness control
- Hi-Lo switch to conserve power
- 500mA dec motor drive w/dynamic braking

LUMICON Digital Quartz Drive **$298**
Dec. output: 24VDC or 110VAC, . . **add $75**

HYPERSENSITIZED FILM

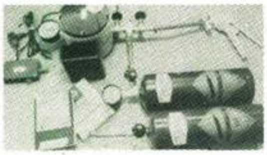
ESSENTIAL FOR GOOD DEEP-SKY ASTROPHOTOS.

NEW KONICA SR-G 3200

35mm film specially hypersensitized by LUMICON. B&W: Use 2415 for nebulae; great for galaxies, too. Fastest Color Slides: Use 3M 1000; Fastest Color Prints: Use Konica SR-G 3200. *Deduct 10% for 3 or more rolls.*

Film Type (35mm unless marked)	Exposures	Price
2415, Ultra-fine grain B&W, red sensitive	36	$10.95
Konica SR-G 3200, Super fast, Amazing Film!	24	$13.95
Kodak Ektar 1000, fast, finer grain	24	$12.95
NEW! Konica SR-G 3200, 120 size, hypered	16	$19.95
Kodak Ektar 125, finest grain color negative	12	$10.95
Scotch 3M 1000, Fastest slide film	12	$12.95
Fujichrome RD100 fine gr. color slide	24	$12.95
Fuji Super HG400 fine gr., high speed neg.	12	$10.95
Konica SR400 120 size medium format	12	$19.95
NEW! 6415 (120 size 2415), hypersensitized	16	$19.95
5072 (SO-279), makes color slides from negs	36	$6.95
Bulk 2415 35mm film, unsensitized	1800	$42.95
4415 (4X5" 2415) 7 mil thick sheets, unsens.	25	$22.95
D-19 B&W developer for 2415 & III a-J	1 gal	$6.95

FILM HYPERSENSITIZATION KIT †



†Patent
#4473636

MODEL 1200 HYPER-KIT™

LUMICON® HYPER-KITS yield 3 to 10-fold true film speed increase in long exposures. **All films benefit.** It's completely safe and simple to do. Each HYPER-KIT includes a film sensitization chamber with all controls, a hand vacuum pump, a thermometer, a film or plate holder, a refillable cylinder of non-flammable "forming gas" for 50-100 batches, and explicit instructions.

Thermostatic temperature regulator for any HYPER-KIT . . . . **add $65**

MAKE YOUR OWN HYPERED FILM

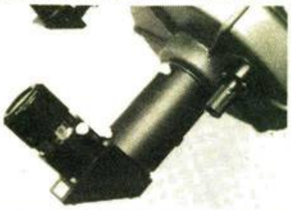
MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415 users! Achieves highest possible film speeds **$325**
MODEL 300 with 2 gas cylinders **$405**
MODEL 600 HYPER-KIT is like the Model 300, but also sensitizes 126/127 and 120/220 larger format film and small glass plates **$395**
MODEL 600 with 2 gas cylinders **$475**
MODEL 1200 HYPER-KIT (see photo) is for 4"X5" plates and film up to 5"X7". Comes with 2 (35 liter) forming gas cylinders and includes a temperature controller **$595**
With electric vacuum pump, for any Model . . . . **add $325**
35 liter cylinder of forming gas w/gauge **$99.50**

LUMICON

Meade & Celestron
LUMICON carries a full line
of telescopes & accessories.
Fast delivery, competitive
prices. Free catalogues.

LUMICON FOR HIGH PERFORMANCE

RICH FIELD! 2° in a C-8



LUMICON Rich-Field Viewer on C-8 with LUMICON 2" star diagonal and 2" eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm clear aperture for **totally unvignetted viewing** with 2" or 1¼" eyepieces. The LUMICON Rich-Field Viewer* system is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer* **$140**

Optional Eyepiece	**TRUE FIELD**	**Price**
Tele Vue 32mm Plossl	1.4°	**add $98**
LUMICON 32mm 2" Erfle†	1.9°	**add $220**
Tele Vue 32mm 2" Wide-Field†	1.9°	**add $365**
Tele Vue 40mm 2" Wide-Field†	2.4°	**add $425**

*Converts to a Cassegrain Easy-Guider for **$109**
†Includes 2" enhanced aluminum Star Diagonal (may not reach focus on some telescopes).

PROTECTIVE DUST COVERS

Protective plugs (left), vinyl dust covers

Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼" O.D. plug, seals focuser .... **4/$2**

2" O.D. plug	**2/$2**	3½" O.D. plug	**$1.50**
1¼", 1⅜"	**3/$2**	7½"	**$8**
1½"	**2/$2**	9½", 10.4"*	**$12**
2"	**2/$2**	12½", 12⅞"*	**$15**
3½"	**$5**	16"*	**$20**
5½"	**$6**	19" (DS-16)	**$29**
*Fits Odyssey		20.5" (Odyssey-II)	**$39**

CELESTRON

ULTIMA™ 11" - PEC

$3495

Celestron Ultima-11, complete 11" f/10 telescope system w/wedge, tripod, starbright coatings, with Periodic Error Correction (PEC), dual-axis hand controller, 2" star diag., 17mm, 30mm Plossls **$3295**

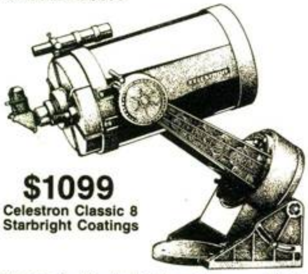
LUMICON Giant Easy-Guider™, combination giant off-axis guider, rich-field viewer w/80mm telecompressor lens for f/5-f/10 operation .. **$398**

Celestron Ultima 8-PEC, 8" f/10 telescope **$2095**

Celestron Powerstar 8-PEC 8" f/10 system **$1650**

Electric declination motor **$119**

CLASSIC 8 . $1099
STARBRIGHT



$1099
Celestron Classic 8
Starbright Coatings

Classic 8 with starbright coatings ... **$1099**
Wedge, **included**; Adj. height tripod .. **$139**
Write or call for full details and a list of standard accessories for any Celestron telescope.

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 2.1" & 1.5" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 95-96% compared to 86-89% for standard aluminum coated mirrors. The extra 7-10% transmission is like adding extra aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with above enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror) **$99.50**
2" (1.83" mirror)(see photo above) .. **$159.00**

NEW ADJUSTABLE PIGGYBACK MOUNT

LUMICON has just designed a new adjustable piggyback mount ideal for all telescopes of 8-14" aperture. It has **both** vertical and sideways adjustment to allow optical alignment. It was designed to allow mounting of the LUMICON SUPER-FINDER on C-8, C-14, etc., but is ideal for any telephoto lenses or small telescopes.

Deluxe Piggyback Mount **$54**
(State telescope type)
LUMICON 12x80mm SUPER-FINDER . **$195**
12x80mm right-angle Amici FINDER . **$259**

TELE VUE™ EYEPIECES USE THE BEST!!

ALL IN STOCK!

Oracle 3" f/7.4 Triplet Apochromat	**$750**
Genesis 4" f/5 4 element fluorite	**$1450**
Renaissance 4" f/5.5 refractor	**$1450**
Complete Equatorial Mount	**$795**
Motor Drive for above mount	**$198**
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	**$89**
1.8x or 2.5x Tele Vue Barlow Lens	**$89**
2" Giant Barlow	**$219**
32mm Plossl, widest true field in 1¼"	**$109**
55mm 2" Plossl, widest possible field	**$219**
15mm Wide-Field, 1¼" eyepiece, 65°	**$135**
19mm Wide-Field, 1¼" eyepiece, 85°	**$145**
24mm Wide-Field, "superb," 65°	**$169**
32mm Wide-Field, 2" eyepiece, 65°	**$239**
40mm Wide-Field, "awesome," 65°	**$299**
4.8mm Nagler, 82° field	**$149**
7mm Nagler, 1¼" eyepiece, 82° field	**$189**
9mm Nagler, 82° field, "the best"	**$219**
11mm Nagler, 82° field, 1¼" or 2"	**$235**
13mm Nagler, 82° field, 1¼" or 2"	**$249**
12mm Nagler, Type II, 82°, 1¼"/2"	**$249**
16mm Nagler, Type II, 82°, 1¼"/2"	**$289**
20mm Nagler, Type II, 82°, 2" only	**$340**
1¼" Paracorr Visual Coma Corrector	**$179**
2" Paracorr Visual Coma Corrector	**$298**

SOLAR PROMINENCE FILTERS

Photo by Jim Baumgardt using a 1½ Å LUMICON Filter, 12½" @ f/70, 1/125 sec, 2415

LUMICON Solar Prominence Filter, 1½ Angstrom bandpass. Includes 77mm energy rejection pre-filter. (state telescope type).... **$595**
3" off-axis metal mask to hold pre-filter C-8, 2080 . **$68** 2080 . **$88** C-11 . **$88** C-14 . **$110**
2" Adapter for C-8, Meade 2080 etc...... **$26**
Adapter for 1¼" or 0.96" focuser........ **$15**
2" adapter for C-80, C-90, C-100 refractors .. **$39.50**

STOP LIGHT POLLUTION WITH LUMICON UHC AND DEEP-SKY FILTERS

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and manmade light pollution and yields 3-6X contrast gain for nebulae and 1-3X contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532 nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 90-96%.

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter.**

The Owl Nebula M-97 in Ursa Major. This large faint 10th magnitude planetary nebula is seen best with a LUMICON UHC Filter. (Photo by Ron Potter on hypered 2415)

LUMICON UHC FILTER™ ULTRA HIGH CONTRAST

The LUMICON UHC FILTER is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm, 90-96% transmission.

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$59.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	**$299.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Set of Both premium **DEEP-SKY** and **UHC Filters** (Save 11%) **1¼" $159.50, 48mm**	**$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** **$99.50, 48mm**	**$199.50**
LUMICON Swan Band Comet Filter (494-518nm bandpass) **1¼"** ... **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines .... **1¼" $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$20.00**

**Premium filters typically have 5-10% higher transmission than any other competing filters. Lumicon Filters include individually measured transmission data.*

"I CAN SEE THE OWL NEBULA!"

Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, "I had never seen M-97. Before using your filter I tried one more time and had the same result — nothing. I attached the UHC Filter and tried again. M-97 was right there, and the sky was very, very dark. I couldn't believe it! I can state with great enthusiasm that the UHC Filter should be standard equipment with any telescope sold in an urban or suburban area. It's that simple."
Tom Kramer, Sayville, NY

J. Marling, 20 min.
8" f/4.5, 2415 film

Horsehead Nebula in Orion. This faint Nebula is seen best visually with a LUMICON H-Beta Filter.

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter

Specify lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$47.00**	**$39.00**
52, 55, 58, 62mm	**$59.00**	**$49.00**
67, 72, 77mm	**$69.00**	**$59.00**
82mm	**$79.00**	

OXYGEN-III FILTER

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at 496nm and 501nm.

Filter type	**1¼**	**48mm**
Lumicon Oxygen-III	**$99.50**	**$199.50**
Lumicon UHC	**$99.50**	**$199.50**
Lumicon Deep-Sky	**$79.50**	**$119.50**
Set UHC and Oxygen-III	**$190.00**	**$380.00**

NOTE: The Oxygen-III Filter is not a substitute, but a complement to the UHC Filter. **1 year guarantee:** You must see nebulae with the O-III filter that are **invisible** without a filter.

NEW COMET FILTERS

Veteran comet observer and hunter Don Machholz (discoverer of Comet Machholz 1978l, 1985e and 1986e) tested the LUMICON Swan Band Comet Filter and says, *"Of seven comets I examined, five were more visible with the filter than without it."* Don Machholz, San Jose, CA

	1¼"	**48mm**	**2"**
Swan Band Filter	**$99.50**	**$199.50**	——
DEEP-SKY Filter	**$79.50**	**$119.50**	**$119.50**

All foreign orders add 6% ($8 minimum)
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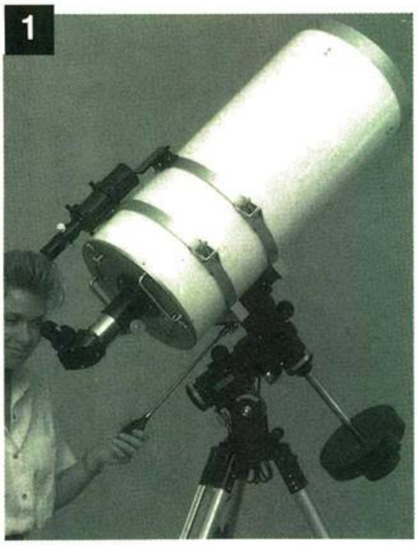
Hours: M-F 9 am - 5 pm, Sat. 11 am - 3 pm

New Astronomy Products

1



RC-10 Ritchey-Chretien Telescope

Optical Guidance Systems now offers a low-cost version of their RC10 Ritchey-Chretien Cassegrain telescope. The new RC10 SL is identical to the existing RC10 model but comes on a modified TeleVue Systems or Vixen DX mount. According to the manufacturer, the f/8.5 Ritchey-Chretien optical system of the RC10 SL provides on-axis images comparable to a good 4-inch refractor and has a flatter field than any common Schmidt-Cassegrain, and with no coma. The optical supplier, Star Instruments, interferometrically tests the optics for a 1/4-wave wavefront. For an additional $100 the manufacturer will supply interferogram certification. Standard features of the RC10 SL include a secondary baffle with a 42% obstruction, a 45mm diameter 1.2° photographic field, a 2-inch focuser (a 2.5-inch focuser is optional), a 2-inch enhanced-silver diagonal and 32mm TeleVue Plössl eyepiece, an 8x50 illuminated finder, a piggyback camera mount, and a 27-inch long fiberglass tube. The complete tube assembly weighs 25 pounds with mounting rings and finder.

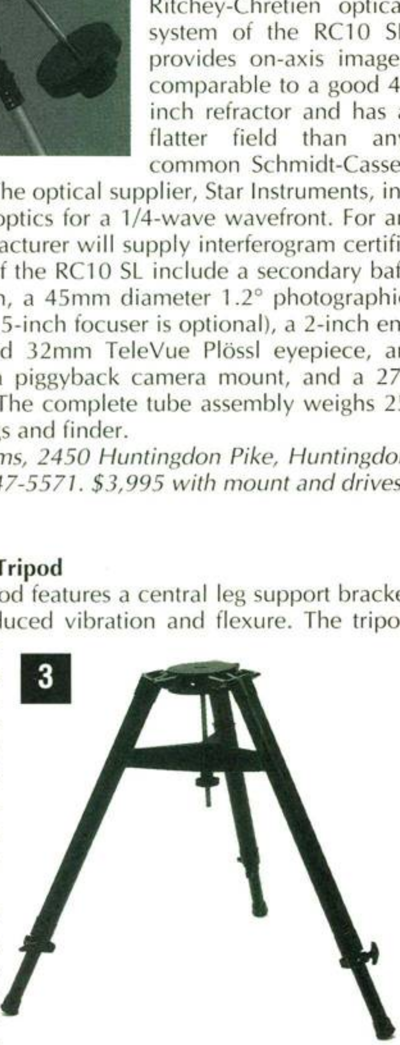
Optical Guidance Systems, 2450 Huntingdon Pike, Huntingdon Valley, PA 19006; (215) 947-5571. $3,995 with mount and drives.

Improved Celestron Field Tripod

The improved Field Tripod features a central leg support bracket for better stability and reduced vibration and flexure. The tripod height is adjustable. Each leg is encased in black rubber for a further reduction of vibration and for protection from accidental scratches and dents. The new Field Tripod is compatible with all 8-inch Celestron Schmidt-Cassegrain telescopes.

Celestron International, 2835 Columbia Street, P.O. Box 3578, Torrance, CA 90503; (800) 421-1526 or (213) 328-9560 (8 a.m. to 4 p.m. Pacific Time). $398.

3



This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.

2

Celestron f/6.3 Reducer/Corrector

This new four-element lens is designed for use with any Celestron f/10 Schmidt-Cassegrain telescope. It reduces the effective f/ratio of the telescope to f/6.3, resulting in shorter exposure times in deep-sky photography, while at the same time flattening the field to provide point-like star images across the entire frame. This also provides sharper guide stars in the field of an off-axis guider, making the task of accurate guiding easier. The diameter of the photographic field is 1.5 inches, sufficient to cover a 35mm frame. The Reducer/Corrector attaches directly to the rear opening of a Celestron Schmidt-Cassegrain and can be used visually to provide rich-field viewing capabilities.

Celestron International, 2835 Columbia Street, P.O. Box 3578, Torrance, CA 90503; (800) 421-1526 or (213) 328-9560 (8 a.m. to 4 p.m. Pacific Time). $238.

4

Software Upgrades for ST-4 CCD Camera

Two new software packages from Santa Barbara Instrument Group extend the capabilities of their ST-4 CCD Star Tracker and Imaging Camera. The CCDTRACK software allows a remote PC computer to control the autotracking functions. The software places an image of the field on the PC monitor where the user can select any object to guide on. The object does not have to be the brightest in the field and does not have to be moving at sidereal speed, which makes it useful for tracking comets. The manufacturer claims a two magnitude improvement in guide star sensitivity. CCDUTIL contains image processing utilities for a PC computer. Included are routines for aligning images, adding images, subtracting dark frames, smoothing, sharpening, flat fielding, contrast enhancement, and saving images in either FITS- or TIFF-format files.

Santa Barbara Instrument Group, 1482 East Valley Road, Suite #J601, Santa Barbara, CA 93108; (805) 969-1851. CCDTRACK: $149; CCDUTIL: $89.00.

5

New Lens Making Kits

Palomar Optical now offers complete lens-making kits for the amateur telescope maker. The kits include all necessary materials to make a classic Fraunhofer doublet design. This includes one fine-annealed Crown element and one fine-annealed Flint element, four plate glass tools, and a full range of grinding and polishing compounds, each contained in reusable, resealable plastic bottles. All lens blanks are plano/plano surfaces but blanks can be molded with rough curves at no extra cost. Glass blanks and grinding compounds are also available separately. All kits are shipped postpaid in the United States.

Palomar Optical Supply, P.O. Box 1310, Wildomar, CA 92395. 3-inch Kit: $109.95; 4-inch: $149.95; 5-inch: $209.95; 6-inch: $279.95; 8-inch: $459.95 plus $25 crating charge for 8-inch kit.

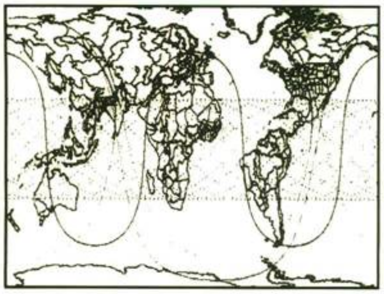
6 Magellan NAV-1000 PLUS

Magellan Systems Corporation, a leading manufacturer of Global Positioning receivers, announces its NAV 1000 PLUS. The compact receiver uses signals from the Global Positioning System (GPS) satellites to provide an accurate fix of the user's geographic location. Position readouts are updated every 2.5 seconds. The PLUS also features a dataport for transmitting navigation information to autopilots, video plotters, radar systems, and sounders. The receiver incorporates a satellite status program that calculates the azimuth and elevation of each available GPS satellite. Developed for marine uses, the PLUS unit is waterproof, buoyant, and resistant to vibration, humidity, and mechanical and thermal shock. The PLUS operates up to seven hours on six AA alkaline batteries or from an external power supply. It is available at marine electronics stores.

Magellan Systems Corporation, 260 East Huntington Drive, Monrovia, CA 91016; (818) 358-2363; FAX (818) 359-4455. $2,695.

7 SATVU Satellite Software

SATVU is a PC-based satellite simulation software package. SATVU animates the field-of-view seen from a satellite, ground station, rocket in flight, or point in inertial space. The scene includes other satellites, Earth continents, the terminator, the Sun, Moon, planets, and over 1,700 stars and deep-sky objects. The ground track view mode displays a zoomable Mercator map of Earth using over 180,000 data points for land masses, rivers, lakes, and national boundaries, overlaid with the satellite ground tracks. A utility program to convert readily available ASCII-format satellite elements into SATVU binary format is included. SATVU requires an AT or 386-compatible computer with math coprocessor, hard disk, and EGA or VGA graphics. The animation update rate is approximately one screen per second on a 20 MHz 386 computer. Screen dumps to Epson, LaserJet, or PaintJet printers are supported.



Applied Research, Inc., 5025 Bradford Boulevard, Huntsville, AL 35805; (205) 837-8600, ext. 1043; FAX (205) 721-1180. $200. A demo disk is available for $5.

8 Leica R-E Camera

The Leica R-E single-lens reflex camera is similar to the more expensive Leica R5 but has just two automatic exposure modes for simple operation and a more affordable price. The two automatic exposure modes are both aperture-priority: one uses metering of selective areas, the other uses average metering. The viewfinder system uses a built-in pentaprism with five interchangeable focusing screens, including a center clear spot screen for astrophotography. Shutter speeds of 1/100 second and Bulb work without battery power. Other features include multiple exposure capability, an electromagnetic self-timer, and LED viewfinder displays of mode, shutter speed, flash readiness, and warnings of over- and underexposure.

Leica USA Inc., 156 Ludlow Avenue, Northvale, NJ 07647; (201) 767-7500; FAX (201) 767-8666. Body only: $1,935. □

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STARS IN YOUR EYES
Light pollution from unshaded high intensity outdoor rural lights, now being installed by the tens of thousands in communities nationwide, is **turning night into day** in the countryside and making the stars unable to be seen. The glare from just one of these sodium/mercury vapor lights — sometimes called "security lights" —can be seen for miles. They shine unwanted into other people's homes even when curtains are drawn. And they interfere with the day and night cycles (circadian rhythms) of our bodies as well as other creatures. Just as society requires that loud music outdoors be turned down or headphones worn, it's only fair that the glaring light-noise from high-intensity outdoor rural lights be shaded and directed only onto the property of persons using them. Please call your state and local officials and encourage them to stop this light pollution. The answer to this problem is simple: make sure these outdoor lights are shaded on the top and sides, locate them closer to the ground and equip them with less powerful bulbs so that people who want them can confine the illumination to their property.

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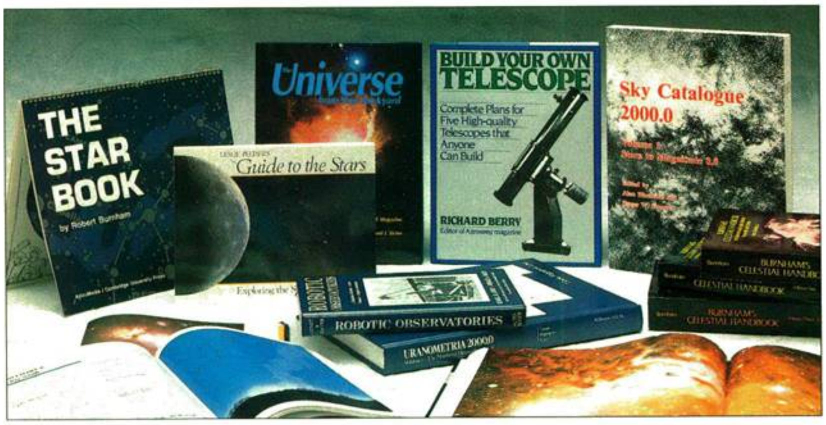

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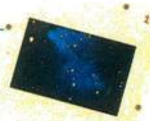

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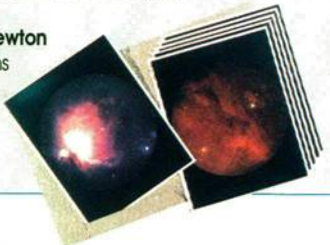

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Product Reviews

A BRIGHTER FOCUSING SCREEN

Beattie Intenscreen, (Beattie Systems, Inc., P.O. Box 3142, Cleveland, TN 37311; (800) 251-6333), Nikon F/F2 model reviewed: $99.95; other models: $69.95.

A good astrophoto is a sharp astrophoto. But try to focus on your subject through a telescope and you immediately discover the task is not so easy. At slow telescopic f/ratios, standard focusing screens become dark and grainy, making it difficult to see your subject let alone focus it.

The Beattie Intenscreen addresses this problem. It features a ground-glass center spot 12 mm in diameter, surrounded by a finely-etched fresnel lens. Beattie offers models for a selection of 35mm cameras that feature interchangeable focusing screens: the Contax RTS, many Nikons, the Olympus OM-series, and the Pentax LX. Intenscreens are currently not available for Canon, Leica, Minolta, or Yashica cameras. While significantly more expensive than the screens from camera manufacturers (which sell for $20 to $40 each), I found that the Intenscreen delivered on its promise of a brighter, sharper image.

To make the comparison I used two camera bodies side-by-side, each equipped with a 50mm f/1.4 lens, and each aimed at the same test target. The images in the camera equipped with the Intenscreen looked brighter than those in the camera with a standard focusing screen. (I used a Nikon Type E screen for the comparison since it has a similar pattern to the Intenscreen — a ground-glass surrounded by fresnel lens pattern.) To match the apparent brightness of the Type E screen, I had to stop down the Intenscreen-equipped camera by two f/stops. Two f/stops is a difference of four times, confirming Beattie's claim of a 400% increase in brightness, although stated as 400% it sounds a lot better than it really is. In practice at the telescope, the Intenscreen provided a gain of just over a magnitude, making it easier to see dim stars across the frame than it is to see them in the standard ground-glass/fresnel lens Nikon screens.

The Intenscreen also provided increased sharpness across the entire screen. In the Nikon screens the images in the fresnel lens area are slightly blurred and broken up by the coarse concentric rings of the fresnel-lens pattern. In the Intenscreen, the fresnel lens is much more finely etched, resulting in clearer, sharper images across the screen. This is a wonderful aid in piggyback and prime-focus deep-sky photography. In addition, unlike some screens, with the Intenscreen there was no splitting or shifting of an image as it crossed the boundary between the plain ground-glass center spot and the surrounding fresnel lens.

Some screens designed for high-magnification photography do not work well on standard focal length lenses. They produce viewfinder images that look vignetted, or darkened, at the corners of the frame. With a 28mm f/2 lens there was indeed a slight vignetting of the corners, which became worse when the lens was stopped down. With a 17mm f/3.5 lens, the vignetting was very noticeable, enough to make it difficult to use this lens at night. With a 55mm f/3.5 Macro lens I found vignetting severe enough that it was difficult to use the Intenscreen with this lens for any type of photography. (In all cases, of course, the vignetting affects only the viewfinder image and not the final image recorded by the film.) However, with other lenses from 50mm to 200mm, the Intenscreen worked very well, making it possible to leave it in the camera as your standard focusing screen for daytime use.

Despite the Intenscreen's brighter images, I found that the light meter of my Nikon F2, which reads off the screen and not the film plane, still gave accurate readings and did not have to be recalibrated when using the Intenscreen. This may not be the case with all cameras. Beattie warns that on some cameras you may have to adjust the ASA/ISO dial to compensate for the extra brightness of the Intenscreen.

To make the Intenscreen even better I'd like to see a model with a 4mm clear center spot with etched crosshairs, similar to Nikon's Type C and Canon's Type I screens. The image in the clear spot remains bright even at very long focal lengths, making it useful for locating deep-sky targets and focusing on planetary images. Such a screen remains my first choice for eyepiece-projection photography of the planets — with the Intenscreen, planetary images were still grainy and fuzzy. But for all other types of astrophotography I can highly recommend the Intenscreen. — *Alan Dyer* ☐

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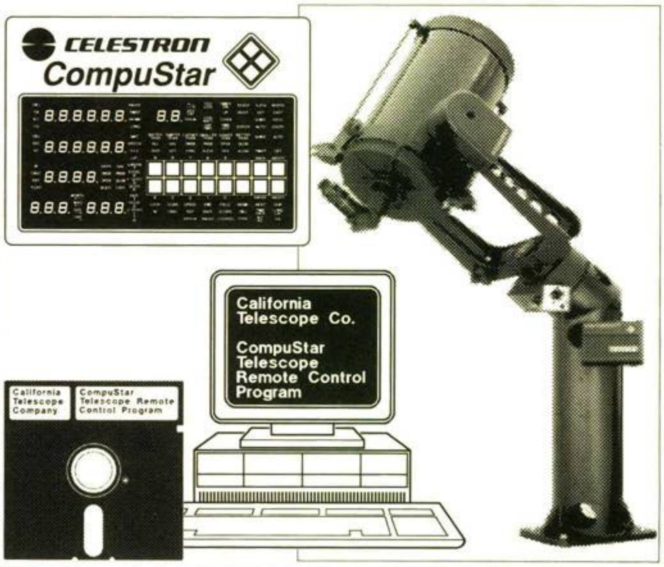
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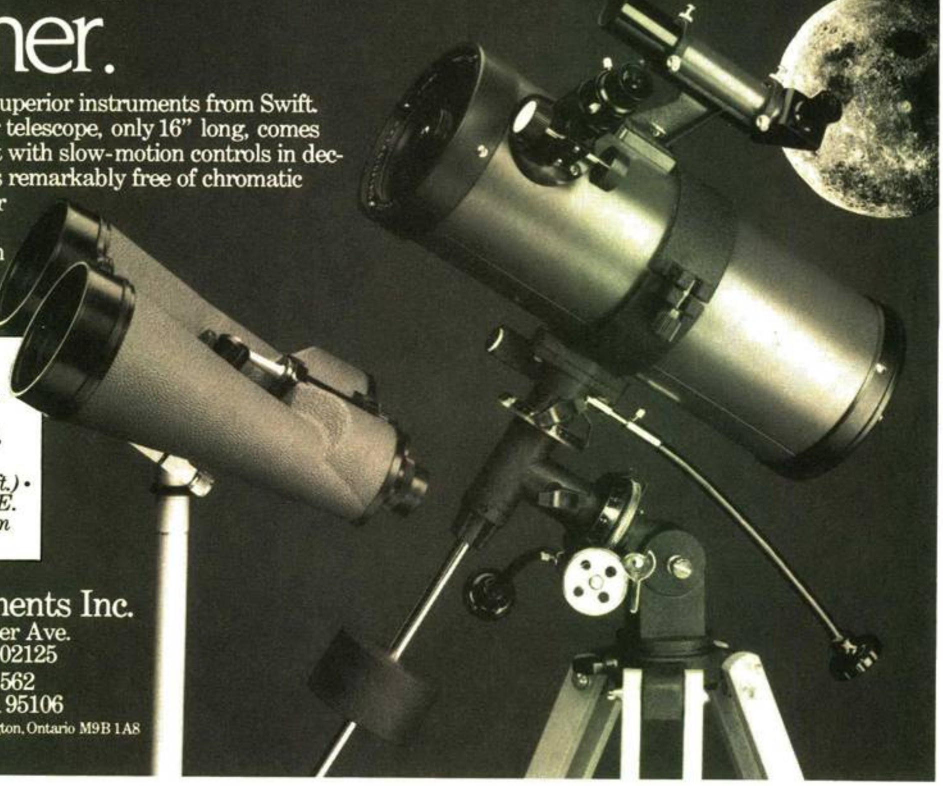

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ASTRONOMICAL LEAGUE

'91 Solar Eclipse
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Astronomical League

We have rooms at the King Kamehameha and Royal Waikoloan hotels on the Kona coast of Hawaii for July 9-13, 1991. Private observing sites at hotels and solar filters to view partial phases safely.

Air travel, five days lodging, and airport transportation estimated at $1700 to $1800 per person/double room occupancy. Cars available.

Side trips to Mauna Kea Observatory, Volcano National Park and other islands planned plus many other attractions.

Dr. Mark Littmann, Univ. of Tennessee; Dr. Jim Zimbelman, Smithsonian Inst., Dr. Ron Schorn, Sky & Telescope, and Ken Willcox, Astronomical League to accompany us. Room is limited, so don't delay.

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Astronomy Books

IDEAL FOR BACKYARD SUPERNOVA HUNTING

Supernova Search Charts and Handbook, by Gregg D. Thompson and James T. Bryan, Jr., (Cambridge University Press, 1989), ISBN 0-521-26721-8, 236 loose charts plus 134-page hardcover book in box, $100.

In 1957, the first supernova was discovered by an amateur astronomer, and since then nearly 30 additional supernovae have been found by amateurs. Professional astronomers of course continue to rack up most of these extragalactic discoveries, thanks to superior equipment. Among amateurs, however, supernova hunting is the lonely pursuit of just a handful, so the roughly 30 discoveries are a pretty good track record. Given this, and when you think how many comets and Milky Way novae amateur astronomers have found, it's a little surprising that more of us *don't* try it.

The advent of the *Supernova Search Charts and Handbook* may swing the tide (if the price isn't too off-putting). It has 236 loose charts neatly packed along with a hardbound handbook into a convenient storage box. The charts, on glossy paper and showing galaxies and stars as white against a black background, are the European A4 size sheet, which is a little taller and a little narrower than our 8 1/2 by 11.

Thompson and Bryan selected 300 galaxies from the *New General Catalogue* and *Index Catalogues* with magnitudes of 11.5 or brighter. A number of fainter galaxies also appear on the charts because they lie near the brighter galaxies. Thus the total number of charted galaxies you can search is some 375.

The top of every chart carries the object's designation in big type (good for low light levels) and the chart in *Sky Atlas 2000.0* on which the galaxy may be found. Also included are the image scale for the chart, the magnitude of the galaxy, its dimensions in minutes of arc, and epoch 1950 and 2000 coordinates.

Galaxy images are halftones of detailed pencil drawings made from photos carefully checked against the eyepiece view. Features or faint stars seen through the telescope but not recorded in the photos due to overexposure have been inserted on the drawings. The resulting charts, unlike photo atlases of galaxies, let you hunt with confidence even into the brightest areas.

Except for the Magellanic Clouds, M31, and M33, the image scale is a uniform 10 arcseconds per millimeter. This provides a 30' field (denoted on every chart as a thin white circle with cardinal directions marked) that approximates a typical low-power field of view. Outside the field only the brighter stars and more prominent objects are charted. The photometric magnitudes of the surrounding field stars are shown on many charts, which helps you estimate limiting and suspected supernova magnitudes when observing. The handbook explains how to use the charts and is a treasure trove of information for the aspiring supernova hunter.

This chart set is an excellent, if pricey, resource for the amateur astronomer. It fills a gap that has long existed in backyard astronomy literature and can be recommended strongly. — *Dana Patchick*

Astronomical History

Catalogue of the Rare Astronomical Books in the San Diego State University Library, Louis A. Kenney, (University of Washington Press, 1988), ISBN 0-295-96801-X, 336 pages, hardcover with slipcase, $125. [The edition consists of 1,000 numbered copies.]

The core of this magnificent collection of Astronomica is the library gathered by the late Ernst Zinner, a professor of the history of astronomy at the University of Munich. The collection now has 211 items, of which 88 were in Zinner's original bequest; 8 books in the collection were printed before 1500, 59 titles date from the 1500s, and 91 from the 1600s. These include either first editions or important later editions of most of the classics of astronomy, such as Bayer's *Uranometria* (1603), Copernicus' *De Revolutionibus* (1566), and Hevelius' *Firmamentum Sobiescianum* (1687). The catalogue has 309 illustrations (16 in color); most books are illustrated by their title pages and many also include text or diagram pages.

Theories of the World from Antiquity to the Copernican Revolution, by Michael J. Crowe, (Dover Publications, 1990), ISBN 0-486-26173-5, 229 pages, paperback, $5.95.

Crowe, who teaches history of science at Notre Dame, has compiled a small and readable book that focuses on the change in thinking that produced the shift in world view from Ptolemy's mathematical and geometric exercises to Copernicus' attempts to explain cosmological reality. After providing the reader with enough quotes from Ptolemy, Copernicus, Tycho, Kepler, and Galileo to let them see how these astronomers thought, Crowe ends his discussion in the year 1615. He stops here because, at this point, regardless of what conservative holdouts said or did — and they were many — the telescope had been invented and a recognizably modern view of the cosmos was in place.

Astronautics and Space
Space Travel: a Technological Frontier, by A. R. De Old, J. W. Judge, and T. Judge, (Davis Publications, 1990), ISBN 0-87192-206-1, 144 pages, paperback, $12.95.

This book provides an overview of how rockets work and details the role that space plays in our civilization.

Almanac of Soviet Manned Space Flight, by Dennis Newkirk, (Gulf Publishing, 1990) ISBN 0-87201-848-2, 391 pages, hardcover, $29.95.

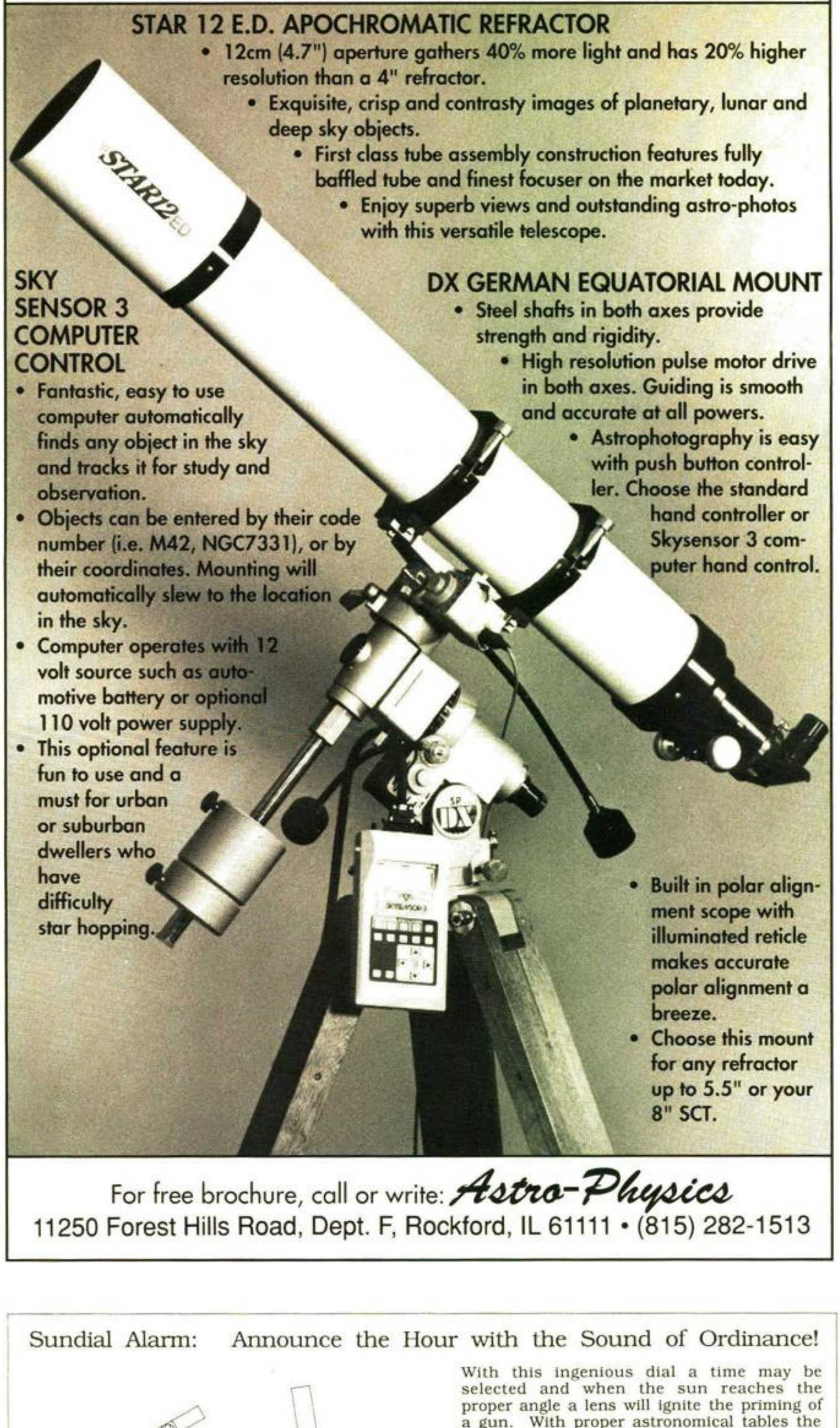
This is a detailed, thorough, and up-to-date report on the entire known Soviet manned program. If you want to know who flew when and what was done on the mission, Newkirk's your author.

SETI Pioneers, by David W. Swift, (University of Arizona, 1990), ISBN 0-8165-1119-5, 436 pages, acid-free paper, hardcover, $35.

If you have any interest at all in the search for extraterrestrial intelligence (SETI), this is a book you have to read. The author, a sociologist at the University of Hawaii, devised a 71-item questionnaire which he used for interviews with 16 of the pioneers of SETI — people such as Frank Drake, Carl Sagan, Ronald Bracewell, John Billingham, Jill Tarter, and Bernard Oliver. The three Soviet scientists interviewed (Iosif Shklovskii, Vsevolod Troitskii, and Nikolai Kardashev) were interviewed by Bernard Oliver using Swift's questionnaire. The results provide an utterly absorbing — and often surprising — look at how these different astronomers and physicists think. (As befits a book intended to document living history "for the ages," it has a sewn binding and was printed on acid-free paper.)

Reference Works
Cambridge Air and Space Dictionary, edited by P. M. B. Walker, (Cambridge University Press, 1990), ISBN 0-521-39763-4 (pbk), 216 pages, hardcover, $29.95, paperback, $12.95.

This dictionary contains about 6,000 entries, of which about 600 are in astronomy. It also includes short (about 1,000 words) essay entries on broad topics such as *galaxy* or *Uranus.* ☐



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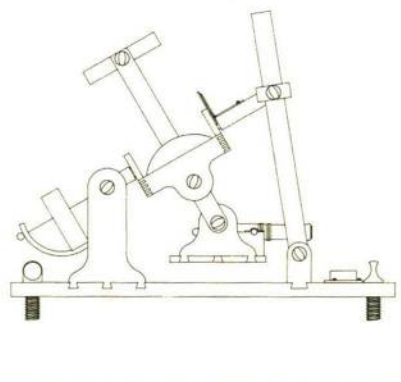

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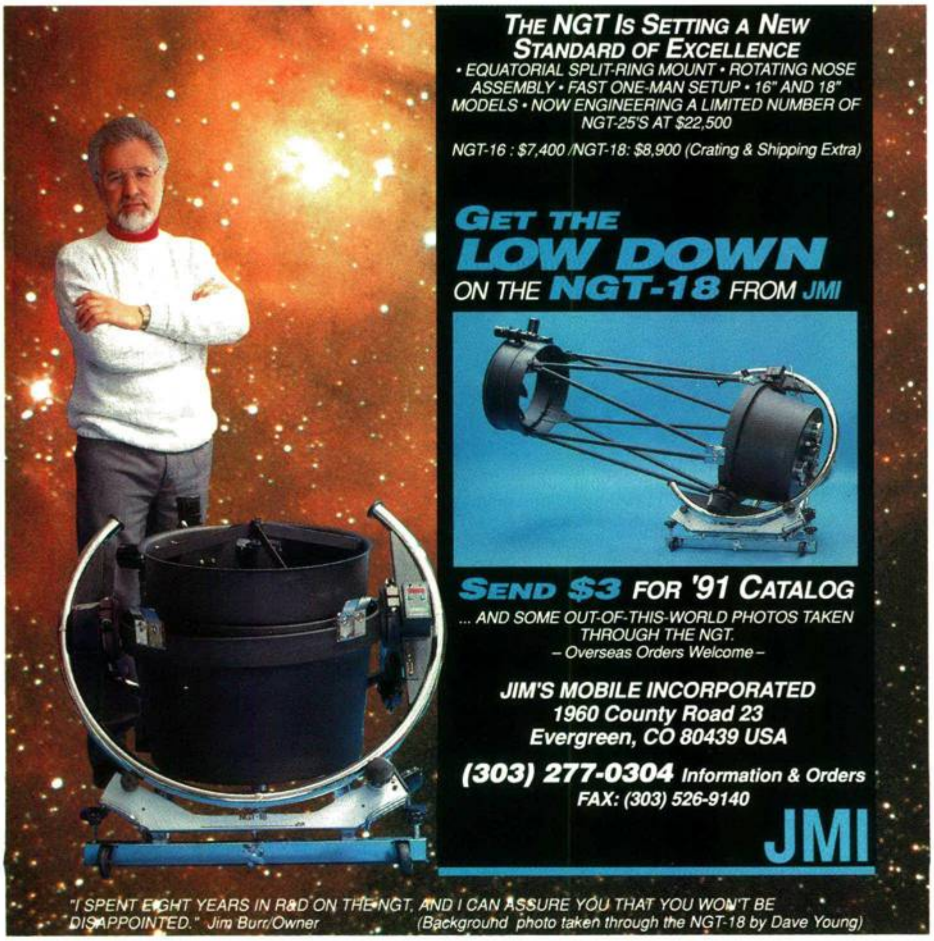

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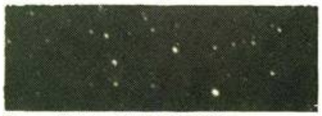

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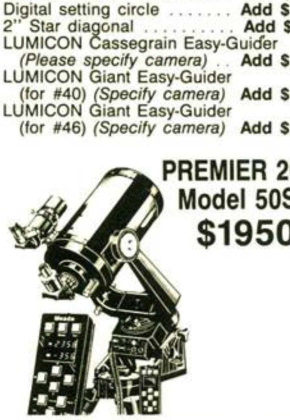

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8 inch 2032mm F/10 optical tube, MTS equatorial pier mount with stand, LX3 drive, #66A manual declination control, 6x30 finderscope, 25mm MA eyepiece diagonal & setting Circles.

Meade List Price Over $1300
Focus Camera Sale Price....... **$887**

2080 BASIC

8 inch 2032mm F/10 schmidt cassegrain optics equatorial fork mount with motor drive, **wedge, tripod,** 6x30 finder, 1¼" diagonal, 25mm eyepiece.
Meade List Price Over $1700 **$917**

2080 Basic MCOG .... CALL

2045D

4 inch 1000mm F/10 optical tube with MCOG multicoatings, equatorial fork mount with reversible DC motor drive & table tripod, 5x24 finder, 1¼" star diagonal, 25mm eyepiece, AA battery pack
Meade List Price Over $1400 **$617**

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2080/Model 40 SD NEW

8 Inch Schmidt Cassegrain

The newest addition to Meade's acclaimed Premier Series features the exclusive PPEC Permanent Periodic Error Correction for the ultimate in accuracy. The included ECC hand controller, 1¼" diagonal & world famous Series 4000 26mm Super Plossl eyepiece allow you to explore the heavens strait out of the box.

Complete Factory Pack Includes;

8 inch 2032mm F/10 optical tube, PPEC drive system, ECC hand controller, 6x30 finderscope, 1¼" diagonal, 26mm Super Plossl eyepiece, Tripod, Wedge, battery pack, AC/DC cords & trunk case.....

Meade List Price Over $2900
Focus Camera Sale Price....... **$1497**

PREMIER SERIES *All Complete Factory Packs*	**2080** *8 Inch*	**2120** *10 Inch*
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76 SD F/6.3 **Smart Drive** ..	3379	4049

Super Wedge option for 2120 Premiers **$219**

4420 Newtonian

The Meade 4420 is the perfect telescope for the beginner. Its' large 4½ inch aperture optical tube & equatorial mounting make it ideal for planetary, deeper space observation or astrophotography.
Special Holiday Sale Price.......... **$317**

REFRACTOR SALE

223 2.4 Inch Alt-Azimuth	**99.95**
289 2.4 Inch Equatorial	**199.95**
291 2.4 Inch Deluxe Equatorial	**274.95**
312 3.1 Inch Alt-Azimuth	**329.95**
323 3.1" Equatorial	**457.95**
Camera Adapter 1¼/.96"	**34.95**
Variable Projection Camera Adapter 1¼"	**48.95**
Eyepieces **1¼"** 4, 6, 12.5, 18mm	**46.95**
Motor Drive 323/4420	**88.95**

MTS-SN6 MCOG

Schmidt Newtonian Telescope

This Meade MTS-SN6 offers a superb 6 inch 750mm F/5 optical tube. It features **MCOG** multi-coated optics #788 motor drive, 1¼/2" focuser, 25mm eyepiece & sturdy MTS equatorial mount with pier.
Special Holiday Sale Price.......... **$594**

MTS-SN8 MCOG

This is the telescope that discovered Comet Austin in 1989. It's 8" 812mm F/4 multicoated optics make it ideal for deep space photography., Add a 2x barlow lens & it becomes a superb planetary telescope. This full factory pack includes #788 motor drive, 1¼/2" focuser, 25mm eyepiece & sturdy MTS equatorial mount with pier.
Meade List Price Over $1300
Focus Camera Sale Price....... **$729**

#66A Dec Arm	**43**	#66C Dec. Arm	**57**
6x30 Finder	**43**	8x50 Finder	**69**

Basic Camera Adapter (SN6/SN8)	**38.95**
#43 Drive Corrector & Inverter	**83.95**

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- 40x Meade eyepiece

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Camera Adapter .... **36** Hard Case	**39.95**
Hybrid Diagonal allows use of 1¼ eyepieces	**48**

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DS-16AB 16" F/4.5 Newtonian as above with Sealmaster Mount Bearings **$1748**

Meetings & Events

February 2
Western Amateur Astronomers Winter Meeting, Bakersfield, California. Contact: Margaret Matlack, 13617 East Bailey, Whittier, CA 90601, (213) 696-9227; or John Griese, 965 Elms Common Drive, Rocky Hill, CT 06067, (203) 721-9529.

February 14-18
7th Annual Winter Star Party, Florida Keys, Florida. Contact: Bob or Sharon Grant, 5401 Southwest 110th Avenue, Miami, FL 33165. Phone: (305) 595-8778.

February 28 - March 3
I.A.P.P.P. Symposium/12th Annual Fairborn Symposium, University of Nevada at Las Vegas, Las Vegas, Nevada. Contact: Diane Pyper Smith, Physics Department, University of Nevada, Las Vegas, NV 89154.

March 14-16
4th Annual Chiefland Star Party, Chiefland, Florida. Sponsored by the Tampa Area Astronomical Society. Contact: John Novak, 9890 82nd Street North, Largo, FL 34647. Phone: (813) 392-4669.

March 30
Astrophoto IX, Thousand Oaks, California. Sponsored by the Ventura County Astronomical Society. Contact: Ventura County Astronomical Society Astrophoto IX, P. O. Box 982, Simi Valley, CA 93062.

April 13
45th Annual Astronomical League North Central Regional Convention, De Pere, Wisconsin. Sponsored by the Neville Public Museum Astronomical Society. Contact: Ronald Parmentier, 161 Rosemont Drive, Green Bay, WI 54301.

April 20
Astronomy Day. Contact: Gary Tomlinson, Astronomy Day Coordinator, c/o Chaffee Planetarium, 54 Jefferson SE, Grand Rapids, MI 49503. Phone: (616) 456-3987. ☐

To ensure publication, please submit announcements to ASTRONOMY at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.

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WANTED — Cabin mate for July 1991 solar eclipse in Hawaii onboard the S. S. Independence, magnificent square portholes, sundeck cabin. I am an eclipse chaser interested in exo-biology and Urantia (Bible of the Universe). Contact Suzette Rochaette, P.O. Box 770977, Cleveland, OH 44107. Phone (216) 521-0221.

ANNOUNCEMENT — Large auction of rare, antique, and collectible astronomical equipment to be held May 18, 1991, by VernonScope and Co. Items by Fitz, Clark, Mogey, Zeiss, Leitz, Sard, Seibert, Ausjena, Bausch and Lomb, and many others. Highlights include 9 1/4" Fitz-Clarke refractor originally at West Point, 13" Clark refractor at Columbia University, and many smaller instruments by famous makers. Those wishing to place consignments in the auction are requested to immediately notify VernonScope and Co., Box 015, Candor, NY 13743. Phone (607) 659-7000. FAX (607) 659-4000.

FOR SALE — 080/GEM Telescope. Setting circles. No clock drive. One eyepiece and tripod included. Like new. Only $650. Contact Dorothy. Phone (815) 395-8021.

FOR SALE — "Outer Space Photography," Paul, 4th edition, 1979, good condition, cover fair. "Astophotography near City Lights," Cocozza, very good condition. £15 each plus postage (change currency to pounds). Contact David McConnell, 13 Thurlow Court, Lincoln, LN2 4SA, England.

FOR SALE — Sold computer system and don't need software! Selling original packages for low prices. Cost $30+ each, selling most for $10! Only one of each! List of IBM games and CAD programs. Contact Jimmy Gilliam, 4834 Hwy 36, W. Searcy, AR 72143.

WANTED — Twenty-five-year-old seeks correspondence with anyone, any age, who is interested in astronomy. My other interests include SF films, film music, history, and nature. Contact Tracey White, 64 Hurst Drive, Waltham Cross, Hertfordshire, EN8 8DO, England.

FOR SALE — Finder, custom wooden case. Superb optical performance. 3 months old. Must sell. $3,750. Also Goto equatorial mount on pier w/motor drive. $1,500. Contact Joseph Nastasi for photos or more info, P.O. Box 59 Wilmington, VT 05363. Phone (802) 368-7570.

WANTED — Information (visual descriptions, anecdotes, primary sources, etc.) about the Coathanger, sometimes known as Brocchi's Cluster or Collinder 399. Contact Gail Clark, 74 Mountain Drive, Pocatello, ID 83204.

WANTED — Fifteen-year-old guy seeks correspondence with some other teens. Especially female earthlings interested in astronomy. All letters will be answered! Contact Andre' LaRouge, 11502 Basye Street #C, El Monte, CA 91732.

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Readings and Resources

Regal Rigel (page 38)

"Insight into Star Death" by Richard Talcott, ASTRONOMY, February 1988. When supernova 1987A exploded in the Large Magellanic Cloud, astronomers found out that blue supergiant stars similar to Rigel can and do explode.

Magellan (page 44)

"*Magellan* Scores at Venus," by David J. Eicher, ASTRONOMY, January 1991. Lots of images.

"Venus, the Hellish Place Next Door," by R. Stephen Saunders, ASTRONOMY, March 1990. Provides an overview of Venus geology.

"Venus Unveiled," by Stephen D. Wall, ASTRONOMY, April 1989. Describes *Magellan* spacecraft and mission.

It Came From Outer Space! *(page 64)*

Thunderstones and Shooting Stars by Robert T. Dodd, (Harvard University Press, 1986). This somewhat technical book examines what we know about the composition of meteorites and what they can tell us about the solar system.

Fireballs, Meteors, and Meteorites by Harold Povenmire, (JSB Enterprises, 1980). Written by a well-known amateur astronomer, this book reviews what amateurs can do to systematically observe meteor showers and fireballs.

ASTRONOMY Tests Ten Nebula Filters *(page 74)*

"A Survey of Light Pollution Filters" by Dan Sheber, DEEP SKY 32, Autumn 1990. A test of a similar batch of nebula filters on a different set of test objects found similar results.

Canis Major (page 80)

Deep Sky Observing with Small Telescopes by David J. Eicher and the editors of *Deep Sky*, (Enslow Publishers, 1989). An introductory observing guide featuring hundreds of objects, including all the major sights in the Canis Major region.

CREDITS

Cover: photo courtesy NASA and Space Telescope Science Institute; *p. 4:* Martin Guth, Canon AE-1 camera, 28mm lens, Kodacolor VR-G 1600 film, 10-second exposure; *p. 22, top:* courtesy P. Drossart, Meudon Observatory, Paris, France; *bottom:* GOES weather satellite image courtesy Sanjay Limaye, Space Science and Engineering Center, University of Wisconsin-Madison; *p. 26:* Michael Porcellino; *p. 30, top:* NASA image; *bottom:* NASA/ESA image; *p. 31, top:* NASA images; *bottom:* NASA image; *p. 32:* NASA image; *p. 33, top:* Gerard Therin, 8-inch SCT at f/6.2, 35-minute exposure, hypered Tech Pan, deep-sky filter; *bottom:* NASA/ESA image: *p. 34, top:* courtesy Francesco Paresce; *bottom:* illustration courtesy Dana Berry, Space Telescope Science Institute; *p.35:* NASA image; *p. 36, top:* ESO image; *middle and bottom:* NASA images; *p. 37, top:* NASA/ESA image; *left:* NASA image; *right:* NASA/ESA image; *p. 38:* Stephen Walther; *pp. 39-43:* illustrations by MariLynn Flynn; *pp. 43-46:* NASA/JPL; *p. 48:* illustration by Paul DiMare; *pp. 64-65:* illustration by Bruce Bond; *p. 67:* photo courtesy Smithsonian Astrophysical Observatory, diagram by Patti Keipe; *p. 68:* illustration by Tom Hunt; *p. 69:* Lanny Ream, August 10, 1972, taken from Idaho-Montana border, five miles west of Lookout Pass, looking east; *p. 70, top:* Jack Newton, 25-inch reflector, SBIG ST-4 CCD camera, 300-second exposure; *bottom left and right:* Donald Parker; *p. 71, top:* Richard Berry, 6-inch f/5 reflector, Photometrics Star IA CCD camera, 300-second exposure; *bottom left:* Richard Berry, color composite made with a 28mm lens, 600-second exposure; *bottom right:* Jack Newton, 25-inch reflector, SBIG ST-4 CCD camera, 300-second exposure; *p. 72:* Patterson Electronics, 8-inch SCT, SS700 camera, 120-second exposure; *p. 73, top:* Richard Berry, Star IA CCD camera, 300-second exposure; *left:* Jack Newton, 25-inch reflector, SBIG ST-4 CCD camera, 300-second exposure; *p. 76:* diagrams by Steve Davis; *p. 78:* diagrams by Steve Davis based on laboratory charts produced by Bob Simpson, National Research Council of Canada, using a Perkin-Elmer 330 spectrophotometer with a slit width of 3 nm and a scan speed of 60 nm/minute; *p. 80, top:* George R. Viscome, 3-inch f/6 refractor, 3M 1000 film, 12-minute exposure; *bottom left and right:* George R. Viscome, 5-inch f/6 reflector, 3M 1000 film, 10-minute exposure; *p. 81:* Jim Barclay, 5-inch f/6 reflector, 1600 ISO film, 20-minute exposure; *p. 83:* Jim Barclay, 5-inch f/6 reflector, 1600 ISO film, 20-minute exposure; *p. 85, top:* Jean Dragesco, 14-inch f/11 SCT at 224x on October 2, 1990, at 19h45m UT; *center:* Michael Sweetman, 6-inch f/10 refractor at various magnifications on October 7, 1990, at 3h UT; *bottom:* Lawrence Hubble, 16-inch Cassegrain at f/70, hypersensitized Tech Pan film, 4-second exposure on October 1, 1990; *p. 86, left:* Ronald E. Royer, 4-inch f/5 astrograph, Ektachrome 200 film, 1-minute exposure on August 10, 1990; *middle:* Jean Dragesco, 7-inch Starfire refractor at f/13, Tech Pan film, 1/2000-second with solar filter and Wratten #58 filter, on July 2, 1990; *bottom:* J. Davy Kilpatrick, 90-inch Steward telescope on Kitt Peak, Arizona; *p. 87:* Gerard Therin, 4-inch f/15 refractor, Tech Pan film, 1/125-second exposure; *p. 88:* Matthew Boulton, 6-inch f/7 reflector at various magnifications on August 26, 1990.

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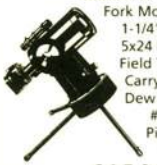

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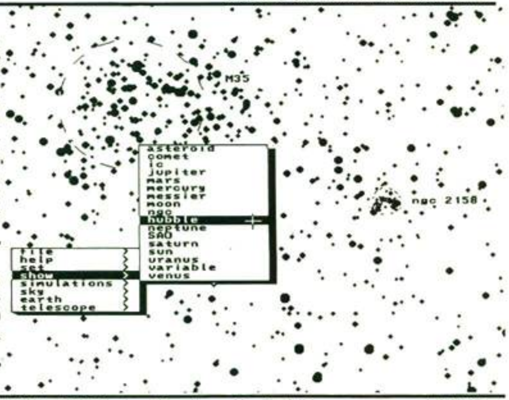

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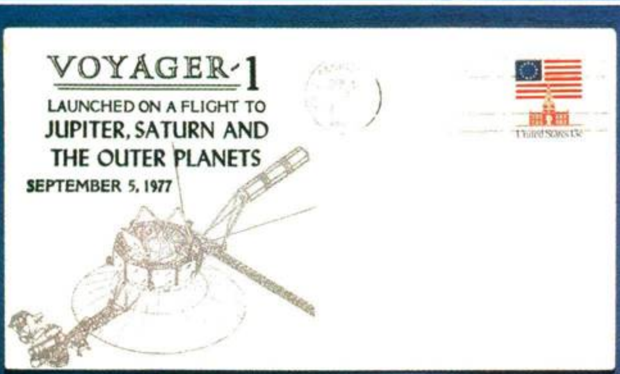
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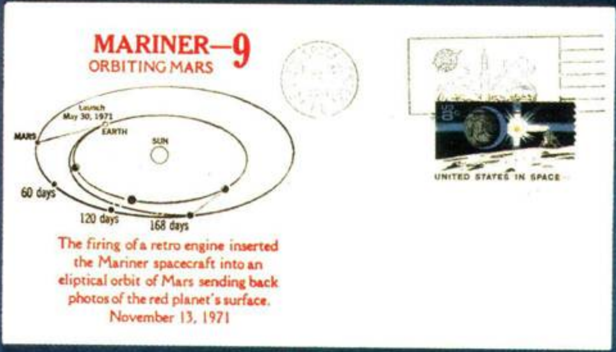
THOMAS STAFFORD
AND
EUGENE CERNAN
PLACED INTO ORBIT FROM
CAPE KENNEDY, FLORIDA
JUNE 3, 1966
LAUNCHING
CAPE CANAVERAL, FL
JUN 3 A.M. 1966
32920
5c
UNITED STATES

APOLLO 16
YOUNG·MATTINGLY·DUKE
Launching
KENNEDY SPACE CENTER
APR 16 P M 1972
A DECADE OF ACHIEVEMENT

APOLLO 15
SCOTT WORDEN IRWIN
LAUNCHING
ANNIVERSARY OF MANS FIRST WALK ON THE MOON
FIRST MAN ON THE MOON
UNITED STATES

PIONEER 10
LAUNCHED FROM
CAPE KENNEDY, FLA.
March 2, 1972
The spacecraft rocketed at record speed to start a 21-month trip to the giant planet Jupiter and eventually to wander forever through distant galaxies.
8c
UNITED STATES IN SPACE


MARINER—9
ORBITING MARS
Launch May 30, 1971
MARS
EARTH
SUN
60 days
120 days
168 days
The firing of a retro engine inserted the Mariner spacecraft into an eliptical orbit of Mars sending back photos of the red planet's surface.
November 13, 1971
8c
UNITED STATES IN SPACE

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